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UNIVERSITY OF ILLINOIS

AGRICULTURAL EXPERIMENT STATION

SOIL REPORT
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URBANA, ILLINOIS

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UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

SOIL REPORT NO. 1

CLAY COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER,
J. H. PETTIT, and J. E. READHIMER

URBANA, ILLINOIS, MARCH, 1911

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CLAY COUNTY SOILS

BY CYRIL G. HOPKINS, J. G. MOSIER, J. H. PETTIT AND J. E. READHIMER

INTRODUCTION

The Illinois County Soil Reports, beginning with Report No. 1, "Clay County Soils," constitute a series of publications separate and distinct from the bulletins and circulars of the Experiment Station. At least three of these county reports will be sent to the Station's entire mailing list. These three are the reports of Clay County, representing the common soils of southern Illinois; Moultrie County, representing the common corn belt soils; and Hardin County, representing the unglaciated Ozark Hills region. As a rule the other soil reports will be sent only to the residents of the respective counties, and to others upon request. This plan requires that each county report shall be as complete as practicable, and consequently this general discussion of soil principles, which appears as an introduction in the Clay County Report, may be found with any necessary modifications as an appendix to every other county report.

A study of the soil map and the tabular statements concerning crop requirements, the plant food content of the different soil types, and the actual results secured from definite field trials with different methods or systems of soil improvement, and a careful study of the discussion of general principles and of the descriptions of individual soil types will furnish the most necessary and useful information for the practical improvement and permanent preservation of the productive power of every kind of soil on every farm in the county.

More complete information concerning the most extensive and important soil types in the great soil areas in all parts of Illinois is contained in Bulletin No. 123, "The Fertility in Illinois Soils," which contains a colored general survey soil map of the entire state.

Other publications of general interest are:

Bulletin No. 76, "Alfalfa on Illinois Soils."
Bulletin No. 94, "Nitrogen Bacteria and Legumes."
Bulletin No. 99, "Soil Treatment for the Lower Illinois Glaciation."
Bulletin No. 115, "Soil Improvement for the Worn Hill Lands of Illinois."
Bulletin No. 125, "Thirty Years of Crop Rotation on the Common Prairie Lands of Illinois."
Circular No. 110, "Ground Limestone for Acid Soils."
Circular No. 127, "Shall we use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils?"
Circular No. 129, "The Use of Commercial Fertilizers."
Circular No. 149, "Some Results of Scientific Soil Treatment" and "Methods and Results of Ten Years' Soil Investigation in Illinois."

NOTE.—Information as to where to obtain limestone, phosphate, bone meal, and potassium salts, methods of application, etc., will also be found in Circular 110.

SOIL SURVEY METHODS

The detail soil survey of a county consists essentially of indicating on a map the location and extent of the different soil types; and, since the value of the survey depends upon its accuracy, every reasonable means is employed to make it trustworthy. To accomplish this object three things are essential: first, careful, well-trained men to do the work; second, an accurate base map upon which to show the results of their work; and, third, the means necessary to enable the men to place the soil type boundaries, streams, etc., accurately upon the map.

The men selected for the work must be able to keep their location exactly and to recognize the different soil types, with their principal varieties and limits, and they must show these upon the maps correctly. A definite system is employed in checking up this work. As an illustration, one soil expert will survey and map a strip 80 rods or 160 rods wide and any convenient length, while his associate will work independently on another strip adjoining this area, and, if the work is correctly done, the soil type boundaries will match up on the line between the two strips.

An accurate base map for field use is absolutely necessary for soil mapping. The base maps are made on a scale of one inch to the mile. The official data of the original or subsequent land survey are used as a basis in the construction of these maps, while the most trustworthy county map available is used in locating temporarily the streams, roads, and railroads. Since the best of these published maps have some inaccuracies, the location of every road, stream, and railroad must be verified by the soil surveyors, and corrected if wrongly located. In order to make these verifications and corrections, each survey party is provided with an odometer for measuring distances, and a plane table for determining the directions of roads, railroads, etc.

Each surveyor is provided with a base map of the proper scale, which is carried with him in the field, and the soil type boundaries, additional streams, and necessary corrections are placed with proper locations upon the map while the mapper is on the area. Each section, or square mile, is divided into 40-acre plots on the map and the surveyor must inspect every ten acres and determine the type or types of soil composing it. The different types are indicated on the map by different colors, pencils being carried in the field for this purpose.

A small auger 40 inches long forms for each man an invaluable tool with which he can quickly secure samples of the different strata for inspection. An extension for making the auger 80 inches long is taken by each party, so that any peculiarity of the deeper subsoil layers may be studied. Each man carries a compass to aid in keeping directions. Distances along roads are measured by an odometer attached to the axle of the vehicle, while distances in the field off the roads are determined by pacing, an art in which the men become expert by practice. The soil boundaries can thus be located with as high a degree of accuracy as can be indicated by pencil on the scale of one inch to the mile.

SOIL CHARACTERISTICS

The unit in the soil survey is the soil type, and each type possesses more or less definite characteristics. The line of separation between adjoining types is usually distinct, but sometimes one type will grade into another so gradually that it is very difficult to draw the line between them. In such exceptional cases, some slight variation in the location of soil type boundaries is unavoidable.

Several factors must be taken into account in establishing soil types. These are (1) the geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial, or cumulose; (2) the topography, or lay of the land; (3) the structure, or the depth and character of the surface, subsurface, and subsoil; (4) the physical or mechanical composition of the different strata composing the soil, as the percentages of gravel, sand, silt, clay, and organic matter which they contain; (5) the texture, or porosity, granulation, friability, plasticity, etc.; (6) the color of the strata; (7) the natural drainage; (8) agricultural value, based upon its natural productiveness; (9) native vegetation; (10) the ultimate chemical composition and reaction.

The common soil constituents are indicated in the following outline:

CONSTITUENTS OF SOILS

Soil Constituents	Organic Matter	Comprising undecomposed and partially decayed vegetable material	
	Inorganic Matter	Clay	.001 mm.* and less
		Silt	.001 mm. to .03 mm.
		Sand	.03 mm. to 1. mm.
		Gravel	1. mm. to 32 mm.
		Stones	32. mm. and over.

*25 millimeters equal 1 inch.
Further discussion of these constituents is given in Circular 82.

GROUPS OF SOIL TYPES

The following gives the different general groups of soils:

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or silt.

Peaty loams—15 to 35 percent of organic matter mixed with much sand and silt and a little clay.

Mucks—15 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 25 percent of clay, usually mixed with much silt.

Clay loams—Soils with from 15 to 25 percent of clay, usually mixed with much silt and some sand.

Silt loams—Soils with more than 50 percent of silt and less than 15 percent of clay, mixed with some sand.

Loams—Soils with from 30 to 50 percent of sand mixed with much silt and a little clay.

Sandy loams—Soils with from 50 to 75 percent of sand.

Fine sandy loams—Soils with from 50 to 75 percent of fine sand mixed with much silt and little clay.

Sands—Soils with more than 75 percent of sand.

Gravelly loams—Soils with 25 to 50 percent gravel with much sand and some silt.

Gravels—Soils with more than 50 percent of gravel.

Stony loams—Soils containing a considerable number of stones over one inch in diameter.

Rock outcrop—Usually ledges of rock having no agricultural value.

More or less organic matter is found in nearly all of the above classes.

Supply and Liberation of Plant Food

The productive capacity of land in humid sections depends almost wholly upon the power of the soil to feed the crop; and this, in turn, depends both upon the stock of plant food contained in the soil and upon the rate at which this is liberated, or rendered soluble and available for use in plant growth. Protection from weeds, insects, and fungous diseases tho exceedingly important is not a positive, but a negative factor in crop production.

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but the rate of liberation is governed by many factors, some of which may be controlled by the farmer, while others are largely beyond his control. Chief among the important controllable factors which influence the liberation of plant food are limestone and decaying organic matter, which may be added to the soil by direct application of ground limestone and farm manure. Organic matter may also be supplied by green manure crops and crop residues, such as clover, cowpeas, straw, and cornstalks. The rate of decay of organic matter depends largely upon its age and origin, and it may be hastened by tillage. The chemical analysis shows correctly the total organic carbon, which represents, as a rule, but little more than half the organic matter; so that 20,000 pounds of organic carbon in the plowed soil of an acre corresponds to nearly 20 tons of organic matter. But this organic matter consists largely of the old organic residues that have accumulated during the past centuries because they were resistant to decay, and 2 tons of clover or cowpeas plowed under may have greater power to liberate plant food than the 20 tons of old inactive organic matter. The recent history of the individual farm or field must be depended upon for information concerning recent additions of active organic matter, whether in applications of farm manure, in legume crops, or in grass root sods of old pastures.

Probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even though plowed alike and at the same time, prepared the same way, planted the same day

with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that the productive power of the land depends primarily upon the stock of plant food contained in the soil and upon the rate at which it is liberated, just as the success of the merchant depends primarily upon his stock of goods and the rapidity of sales. In both cases the stock of any commodity must be increased or renewed whenever the supply of such commodity becomes so depleted as to limit the success of the business, whether on the farm or in the store.

As the organic matter decays, certain decomposition products are formed, including much carbonic acid, some nitric acid, and various organic acids, and these have power to act upon the soil and dissolve the essential mineral plant foods, thus furnishing nitrates, phosphates, and other salts of potassium, magnesium, calcium, etc., for the use of the growing crop.

As already explained, fresh organic matter decomposes much more rapidly than the old humus, which represents the organic residues most resistant to decay and which consequently have accumulated in the soil during the past centuries. The decay of this old humus can be hastened both by tillage, which maintains a porous condition and thus permits the oxygen of the air to enter the soil more freely and to effect the more rapid decomposition or oxidation of the organic matter, and also by incorporating with the old resistant residues some fresh organic matter, such as farm manure, clover roots, etc., which decay rapidly and which thus furnish or liberate organic matter and inorganic food for bacteria, which, under such favorable conditions appear to have power to attack and decompose the old humus. It is probably for this reason that peat, a very inactive and inefficient fertilizer when used by itself, becomes much more effective when incorporated with fresh farm manure, so that when used together, two tons of the mixture may be worth as much as two tons of manure, but if applied separately, the peat has little value. Bacterial action is also promoted by the presence of limestone.

It should be kept in mind that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all plants, only one (hydrogen) from water, and seven from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes), in case the amount liberated from the soil is insufficient; but even these plants (which include only the clovers, peas, beans, and vetches among our common agricultural plants) secure six elements from the soil (phosphorus, potassium, magnesium, calcium, iron, and sulfur), and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Plants are made of these plant-food elements in just the same sense that a building is made of wood and iron, brick, stone, and mortar. Without

materials, nothing material can be made. The normal temperature, sunshine, rainfall, and length of season in southern Illinois are sufficient to produce 50 bushels of wheat per acre, 100 bushels of corn, 100 bushels of oats, and 4 tons of clover hay; and, where the land is properly drained and properly tilled, such crops would frequently be secured *if the plant foods were present in sufficient amount and liberated at a sufficiently rapid rate to meet the absolute needs of the crops.*

CROP REQUIREMENTS

The accompanying table shows the requirements of such crops for the five most important plant food elements which the soil must furnish. (Iron and sulfur are supplied normally in sufficient abundance compared with the amounts needed by plants, so that they are not known ever to limit the yield of crops):

TABLE 1.—PLANT FOOD IN WHEAT, CORN, OATS, AND CLOVER

Produce		Nitrogen, pounds	Phosphorus, pounds	Potassium, pounds	Magnesium, pounds	Calcium, pounds
Kind	Amount					
Wheat, grain	50 bu.	71	12	13	4	1
Wheat straw	2½ tons	25	4	45	4	10
Corn, grain	100 bu.	100	17	19	7	1
Corn stover	3 tons	48	6	52	10	21
Corn cobs	½ ton	2	..	2	..	..
Oats, grain	100 bu.	66	11	16	4	2
Oat straw	2½ tons	31	5	52	7	15
Clover seed	4 bu.	7	2	3	1	1
Clover hay	4 tons	160	20	120	31	117
Total in grain and seed		244*	42	51	16	4
Total in four crops		510*	77	322	68	168

To be sure, these are large yields, but shall we try to make possible the production of yields only half or a quarter as large as these, or shall we set as our ideal this higher mark, and then approach it as nearly as possible with profit? Among the four crops, corn is the largest, with a total yield of more than six tons per acre; and yet the 100-bushel crop of corn is often produced on rich pieces of land in good seasons. In very practical and profitable systems of farming, the Illinois Experiment Station has produced, as an average of the six years, 1905 to 1910, a yield of 87 bushels of corn per acre in grain farming (with limestone and phosphorus applied, and with crop residues and legume crops turned under), and 90 bushels per acre in live-stock farming (with limestone, phosphorus, and manure).

On the Edgewood Experiment Field, less than five miles from the north line of Clay County, and on the common prairie land of southern Illinois, yields have been obtained as high as 91 bushels per acre of corn, 74 bushels of oats, and 2.91 tons of air-dry clover hay, in the first cutting, and probably more than 1 ton in the second crop, which, however, was plowed under without weighing.

*These amounts include the nitrogen contained in the clover seed or hay, which, however, may be secured from the air.

LEGEND

UPLAND PRAIRIE SOILS

K 30 330 — Gray silt loam on tight clay

28 328 — Brown-gray silt loam on tight clay

Z 29 329 — Drab silt loam

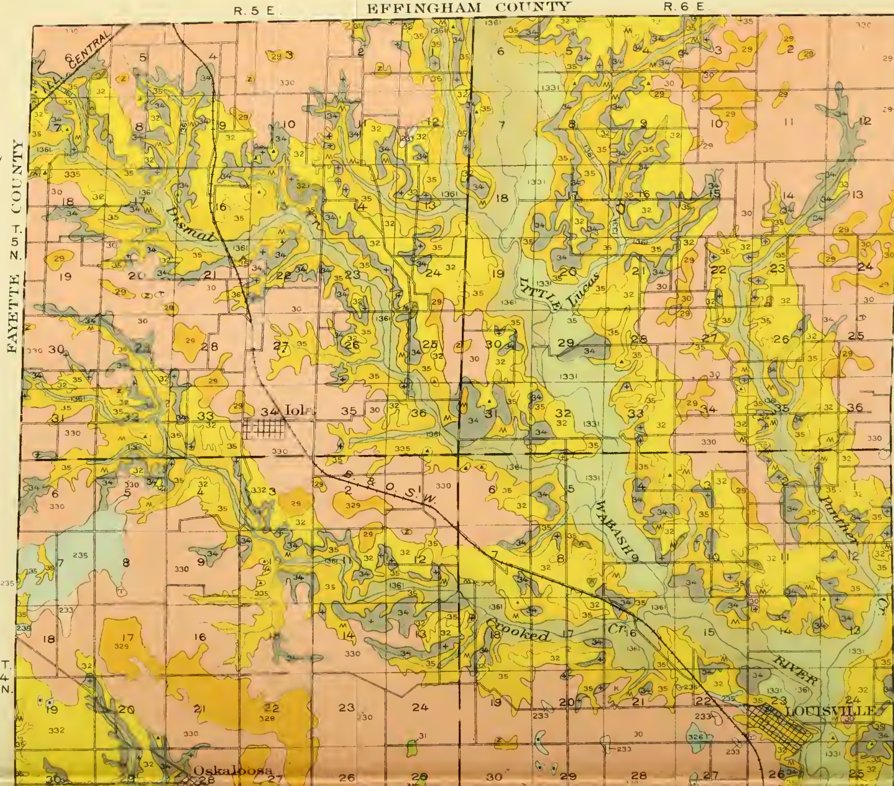
261 326 — Brown silt loam on clay

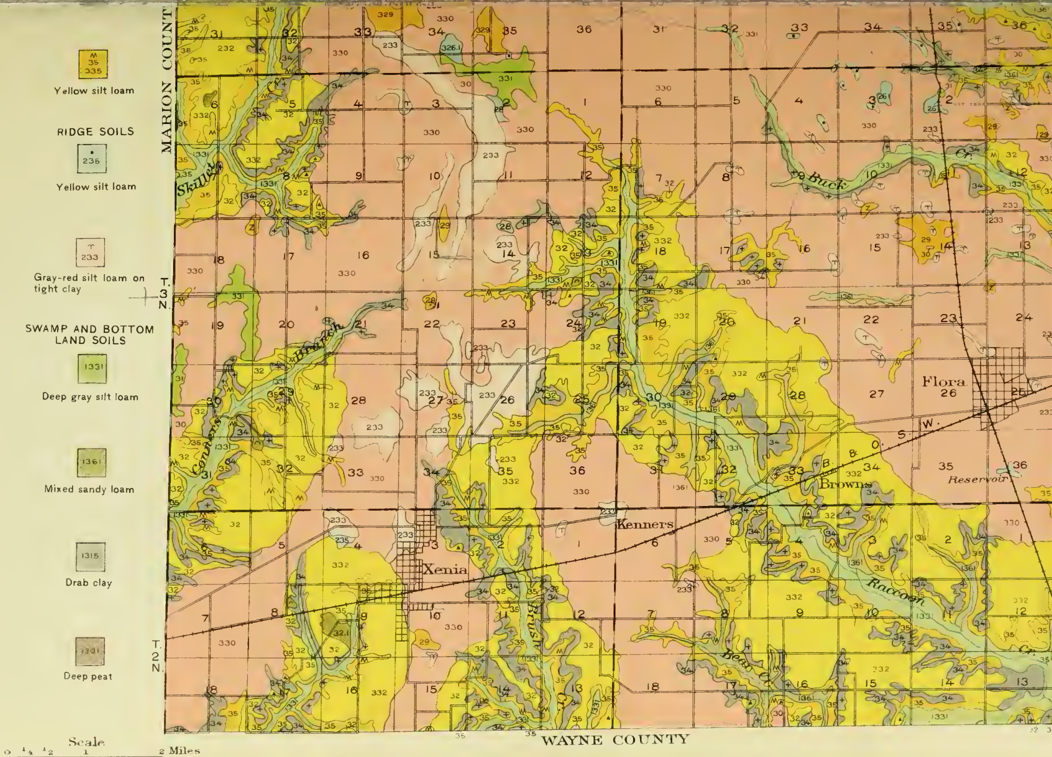
31 331 — Deep gray silt loam

UPLAND TIMBER SOILS

32 332 — Light gray silt loam on tight clay

321 3321 — White silt loam on tight clay





SOIL SURVEY MAP OF CLAY COUNTY

UNIVERSITY OF ILLINOIS AGRICULTURAL EXPERIMENT STATION

THE FERTILITY IN CLAY COUNTY SOILS

ORIGIN OF SOIL MATERIAL

Clay County was covered by the Illinoisan ice sheet, which generally leveled down hills and filled valleys, and left that part of the state as a broad level expanse broken only by a few morainal or preglacial ridges, remnants of which now form our ridge soils. The ice sheet in its movement southward carried large amounts of earthy material of various sizes, including boulders, gravel, sand, silt and clay, which were deposited when the ice melted, forming what is known as till, boulder clay, or glacial drift, which may be recognized readily by its composite character.

After the ice sheet melted, the surface of the glacial drift was slowly and gradually changed into a soil which varied somewhat as soils do now.

At the close of the Iowan glaciation, which followed the Illinoisan, the entire state was covered with a wind-blown dust, known as loess, which was deposited somewhat uniformly over this region to a depth of from 4 to 10 feet, burying the old soil completely. A new soil was formed from this fine material by the subsequent weathering and the accumulation of organic matter, which has been modified to form the present soils. The old buried soil, known as the Sangamon soil, is sometimes exposed along streams or roadsides, occasionally as a dark heavy stratum two or three feet thick, while in other places it is represented only by a weathered surface of the glacial drift.

TABLE 2.—SOIL TYPES OF CLAY COUNTY

Soil type No.	Names	Area in acres	Percent of total
	(a) Upland Prairie Soils (Page 22)		
330	Gray silt loam on tight clay	110,720	37.000
328	Brown-gray silt loam on tight clay	960	.330
329	Drab silt loam	14,400	4.800
326.1	Brown silt loam on clay	824	.270
331	Deep gray silt loam	1,760	.590
	(b) Upland Timber Soils (Page 26)		
332	Light gray silt loam on tight clay	51,200	17.130
332.1	White silt loam on tight clay	224	.073
334	Yellow-gray silt loam	21,240	7.090
335	Yellow silt loam	41,760	14.000
	(c) Ridge Soils (Page 29)		
235	Yellow silt loam	2,560	.854
233	Gray-red silt loam on tight clay	9,180	3.000
	(d) Swamp and Bottom land Soils (Page 30)		
1331	Deep gray silt loam	31,680	10.580
1361	Mixed sandy loam	12,800	4.270
1315	Drab clay	25	.008
1301	Deep peat	15	.005
	Totals	299,348	100.000

The data in Table 3 represent the total amounts of plant food found in 2 million* pounds of the surface soil, which corresponds to an acre of soil about 6⅔ inches deep, including at least as much soil as is ordinarily turned with the plow, and representing that part of the soil with which we incorporate the farm manure, limestone, phosphate, or other fertilizer applied in soil improvement. This is the soil stratum upon which we must depend in large

*The amounts are for only 1 million pounds of the peat soil because its specific gravity is only one-half that of normal soils.

part to furnish the necessary plant food for the production of the crops grown.

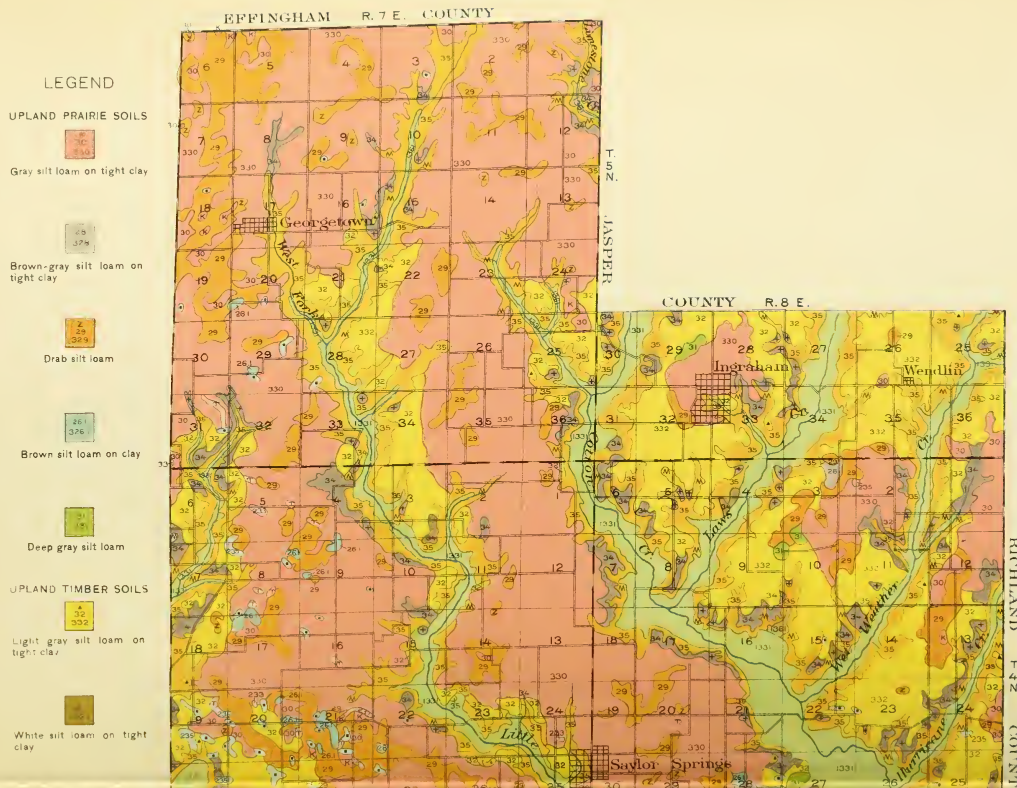
In Table 3 is recorded the invoice of the plowed soil, showing the total amounts of these five elements of plant food contained in each of the different types of soil in Clay County. (For more details see Bulletin 123.)

TABLE 3.—FERTILITY IN THE SOILS OF CLAY COUNTY, ILLINOIS
Average pounds per acre in 2 million pounds of surface soil (about $6\frac{2}{3}$ inches)

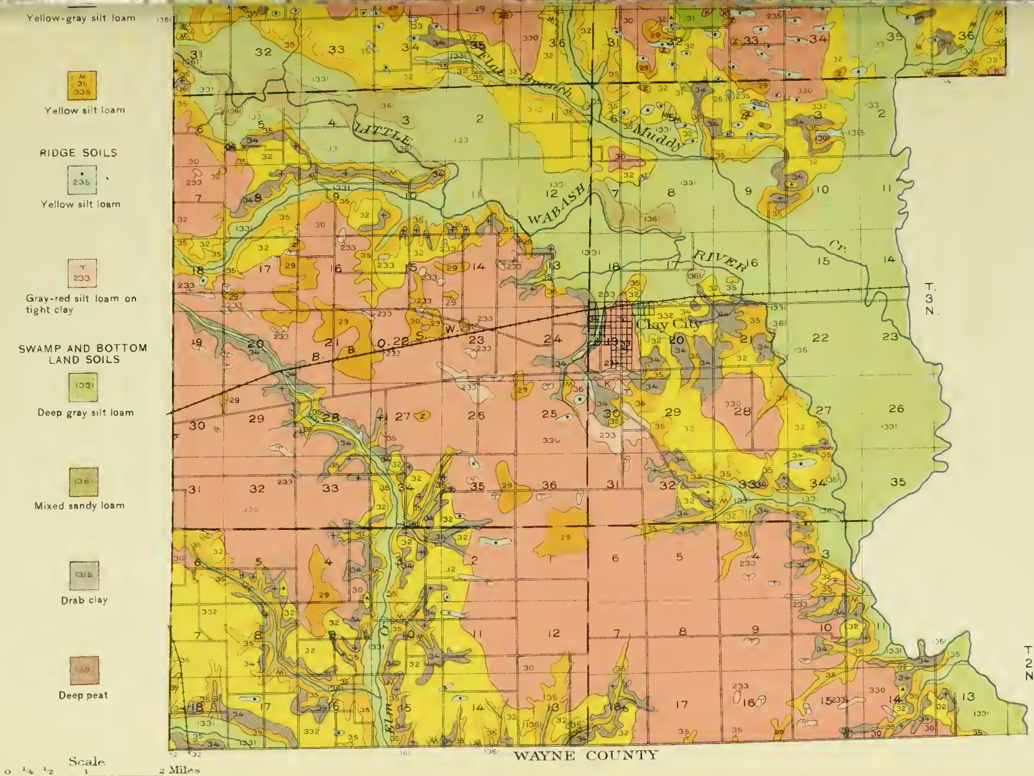
Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone required
	Upland Prairie Soils								
330	Gray silt loam on tight clay	26970	2790	750	24830	4690	3420		1130
328	Brown-gray silt loam on tight clay...	30600	3020	1020	25760	5780	4020		160
329	Drab silt loam	23640	2560	630	25110	4560	6270		1520
326.1	Brown silt loam on clay	30740	3320	700	24700	5520	7720		1500
331	Deep gray silt loam....	20800	2180	600	24220	3000	4900		1640
	Upland Timber Soils								
332	Light-gray silt loam on tight clay...	17810	1580	760	27860	4310	4620		480
322.1	White silt loam on tight clay	16980	1120	400	29380	4940	4060		840
334	Yellow-gray silt loam....	19600	1650	550	30200	5490	6920		40
335	Yellow silt loam	16990	1540	510	31430	3800	3000		2250
	Ridge Soils								
235	Yellow silt loam........	41970	3890	820	29500	8140	6040		140
233	Gray-red silt loam on tight clay...	27380	2720	760	27300	5200	4320		1040
	Swamp and Bottom-land Soils								
1331	Deep gray silt loam....	31470	2910	1350	34740	7700	7580		100
1361	Mixed sandy loam........	26950	2700	750	31410	6350	7950		80
1315	Drab clay.....	43960	4180	1040	35300	10920	8160		40
1301	Deep peat* ...	297660	16790	930	6190	7240	107900	224680	

The importance of maintaining a rich surface soil cannot be too strongly emphasized. It is well illustrated by data from the Rothamsted Experiment Station, the oldest in the world. Thus on Broadbalk field, where wheat has been grown since 1844, the average yields for the ten years, 1892 to 1901 were 12.3 bushels per acre on plot 3 (unfertilized) and 31.8 bushels on plot 7 (well fertilized), but the amounts of both nitrogen and phosphorus in the subsoil (9 to 27 inches) were distinctly greater in plot 3 than in plot 7, thus showing that the higher yields from plot 7 were due to the fact that the plowed soil had been enriched. In 1893, plot 7 contained per acre in the surface soil (0 to 9 inches) about 600 pounds more nitrogen and 900 pounds more phosphorus than plot 3. Even a rich subsoil has little value if it lies beneath a worn-out surface.

*Amounts reported are from 1 million pounds of peat soil.



LEGEND
UPLAND PRAIRIE SOILS
Gray silt loam on tight clay
Brown-gray silt loam on tight clay
Drab silt loam
Brown silt loam on clay
Deep gray silt loam
UPLAND TIMBER SOILS
Light gray silt loam on tight clay
White silt loam on tight clay
EFFINGHAM R. 7 E. COUNTY
JASPER COUNTY R. 8 E.
T. 5 N.
T. 4 N.
RICHLAND COUNTY
Georgetown
Ingraham
Wendlin
Saylor Springs
West Fork
Limestone Cr.
Cotton
Laws Cr.
Cr.
West Watcher
Little
Hurricane Cr.



SOIL SURVEY MAP OF CLAY COUNTY
UNIVERSITY OF ILLINOIS AGRICULTURAL EXPERIMENT STATION

By easy computation it will be found that not one of the prairie soils of Clay County contains enough total nitrogen in the plowed soil for the production of maximum crops for ten rotations; while the upland timber soils contain as an average only about half as much nitrogen as the prairie land.

Practically the same condition obtains with respect to phosphorus, only two of the eleven upland soils containing as much of that element as would be required for ten crop rotations if such crop yields were secured as suggested in Table 1; and in case of the cereals it will be seen that about three-fourths of the phosphorus taken from the soil is deposited in the grain, while only one-fourth remains in the straw or stalks. If only the grain and seed were sold from the farm the total supply of phosphorus in the plowed soil is no more than would need to leave the farm during the full time of one life (70 years).

On the other hand, the potassium is sufficient for 2000 years, if only the grain is sold, or for 300 years if the total crops are removed; and the corresponding figures are about 1200 and 300 years for magnesium, and about 3000 and 100 years for calcium.

Thus when measured by the actual crop requirements for plant food magnesium and calcium are more limited than potassium. But with these elements we must also consider the loss by leaching. As an average of 90 analyses* of Illinois well-waters drawn chiefly from glacial sands, gravels, or till, 3 million pounds of water (about the average annual drainage per acre for Illinois) contained 11 pounds of potassium, 130 of magnesium, and 330 of calcium. These figures are very significant, and it may be stated that if the plowed soil is well supplied with the carbonates of magnesium and calcium, then a very considerable proportion of these amounts will be leached from that stratum. Thus the loss of calcium from the plowed soil of an acre at Rothamsted, England, where the soil contains plenty of limestone, has averaged more than 300 pounds a year as determined by analyzing the soil in 1865 and again in 1905.

It is of interest to note that thirty crops of clover of 4 tons each would require 3510 pounds of calcium, while the most common prairie land (gray silt loam on tight clay) contains only 3420 pounds of total calcium in the plowed soil of an acre.

These general statements relating to the total quantities of plant food in the plowed soil certainly emphasize the fact that the supplies of some of these necessary elements of fertility are extremely limited when measured by the needs of large crop yields for even one or two generations of people. We must also consider, however, the question of the rate at which these plant food elements may be liberated and thus made available for plant growth.

Methods of Liberating Plant Food

Limestone and decaying organic matter are the principal materials the farmer can utilize most profitably to bring about the liberation of plant food.

The limestone corrects the acidity of the soil and thus encourages the development not only of the nitrogen-gathering bacteria which live in the nodules on the roots of clover, cowpeas, and other legumes, but also of the nitrifying bacteria which have power to transform the insoluble and unavailable organic nitrogen into soluble and available nitrate nitrogen.

*Reported by Doctor Bartow and associates, of the Illinois State Water Survey.

At the same time the products of this decomposition have power to dissolve the minerals contained in the soil, such as potassium and magnesium, and also to dissolve the insoluble phosphate and limestone which may be applied in low-priced forms.

Tillage, or cultivation, also hastens the liberation of plant food by permitting the air to enter the soil and burn out the organic matter; but it should never be forgotten that tillage is wholly destructive, that it adds nothing whatever to the soil, but always leaves the soil poorer. Tillage should be practiced so far as is necessary to prepare a suitable seed-bed for root development and also for the purpose of killing weeds, but more than this is unnecessary and unprofitable in seasons of normal rainfall; and it is much better actually to enrich the soil by proper applications or additions, including limestone and organic matter (both of which have power to improve the physical condition as well as to liberate plant food) than merely to hasten soil depletion by means of excessive cultivation.

PERMANENT SOIL IMPROVEMENT

The best and most profitable methods for the permanent improvement of the common soils of Clay County are as follows:

(1) Apply at least two tons (and better five tons) per acre of ground limestone, preferably at times magnesian limestone ($CaCO_3$ $MgCO_3$) which contains both calcium and magnesium, and has slightly greater power to correct soil acidity, ton for ton, than the ordinary calcium limestone ($CaCO_3$). Afterward continue to apply about two tons per acre of ground limestone every four to six years.

(2) Adopt a good rotation of crops, including a liberal use of legumes, and increase the organic matter of the soil either by plowing under the legume crops and other crop residues (straw and corn stalks) or by using for feed and bedding practically all of the crops raised and returning the manure to the land with the least possible loss. No one can say in advance what will prove to be the best rotation of crops, because of variation in prices and seasons, but the following are suggested to serve as models or outlines:

First year, corn (with some winter legume, such as red clover, alsike, sweet clover, or alfalfa, or a mixture, seeded on one-half of the field at the last cultivation).
Second year, oats or barley on one-half and cowpeas or soybeans where the winter catch crop is plowed down.
Third year, wheat or rye (with clover or clover and grass).
Fourth year, (1) clover, or (2) clover and timothy, or (3) clover and red top.
Fifth year, (1) wheat and clover, or (2) timothy and clover, or (3) red top.
Sixth year, (1) clover, or (2) clover and timothy, or (3) red top.

In grain farming, with wheat grown the third and fifth years, most of the coarse products should be returned to the soil, and the clover may be clipped and left on the land (only the clover seed being sold the fourth and sixth years); or in live-stock farming, the clover may be reseeded each spring, if necessary to maintain the stand, and the field used three years for timothy and clover pasture and meadow as desired. If red top is seeded the clover will usually make seed or both hay and seed the fourth year, and red-top seed may be sold the fifth and sixth years. To avoid clover sickness it may sometimes be necessary to substitute red clover or alsike for the other in about every third rotation, and to discontinue their use in the catch-crop mixture. If the corn crop is not too rank, cowpeas or soybeans may also

be used as a catch-crop and, if necessary to avoid disease, these may well alternate in successive rotations.

For easy figuring it may well be kept in mind that the following amounts of nitrogen are required for the produce named:

1 bushel of oats (grain and straw) requires 1 pound of nitrogen.
1 bushel of corn (grain and stalks) requires 1½ pounds of nitrogen.
1 bushel of wheat (grain and straw) requires 2 pounds of nitrogen.
1 ton of timothy requires 24 pounds of nitrogen.
1 ton of red top requires 21 pounds of nitrogen.
1 ton of average manure contains 10 pounds of nitrogen.
1 ton of clover contains 40 pounds of nitrogen.
1 ton of cowpeas contains 43 pounds of nitrogen.

The roots of clover contain about half as much nitrogen as the tops, and the roots of cowpeas contain about one-tenth as much as the tops.

Soils of moderate productive power will furnish as much nitrogen to clover (and more to cowpeas) than will be left in the roots and stubble. For grain crops, as wheat, corn, and oats, about two-thirds of the nitrogen is contained in the grain and one-third in the straw or stalks.

(3) On all of the lands not subject to overflow (or susceptible to serious erosion by surface washing or gullying) apply the element phosphorus in considerably larger amounts than are required to meet the actual needs of the crops desired to be produced. The abundant information thus far secured shows positively that fine-ground natural rock phosphate can be used successfully and very profitably, and clearly indicates that this material will be the most economical form of phosphorus to use in all ordinary systems of permanent, profitable soil improvement. The first application may well be one ton per acre (at least one-half ton should be used), and subsequently about one-half ton per acre every four to six years should be applied, at least until the phosphorus content of the plowed soil reaches 2000 pounds per acre, which will require a total application of five or six tons per acre of raw phosphate containing 12½ percent of the element phosphorus. Steamed bone meal and even acid phosphate may be used in emergencies, but it should always be kept in mind that phosphorus delivered in southern Illinois costs about 3 cents a pound in raw phosphate (direct from the mine in carload lots), more than 10 cents a pound in steamed bone meal, and more than 12 cents a pound in acid phosphate, both of which cost too much per ton to permit their common purchase by farmers in carload lots, which is not the case with limestone or raw phosphate.

Phosphorus once applied to the soil remains in it until removed in crops, unless carried away mechanically by soil erosion. (The loss by leaching is only about 1½ pounds per acre per annum, so that more than 150 years would be required to leach away the phosphorus applied in one ton of raw phosphate).

The phosphate and limestone may be applied at any time during the rotation, but a good method is to apply the limestone after plowing and work it into the surface soil in preparing the seed bed for wheat, oats, rye, or barley, where clover is to be seeded, while phosphate is best plowed under with farm manure, clover, or other green manures, which serve to liberate the phosphorus.

(4) Until the supply of decaying organic matter has been made adequate, some temporary benefit may be derived from the use of a

soluble salt or mixture of salts, such as kainit, which contains both potassium and magnesium in soluble form and also some common salt (sodium chlorid). About 600 pounds per acre of kainit applied and turned under with the raw phosphate will help to dissolve the phosphorus as well as to furnish available potassium and magnesium, and for a few years such use of kainit will no doubt be profitable on lands deficient in organic matter, but the evidence thus far secured indicates that its use is not absolutely necessary and that it will not be profitable after adequate provision is made for decaying organic matter, since this will necessitate returning to the soil either all produce except the grain (in grain farming) or the manure produced in live-stock farming. (Where hay or straw are sold, manure should be bought.)

TABLE 4.—FERTILITY IN THE SOILS OF CLAY COUNTY, ILLINOIS
Average pounds per acre in 4 million of subsurface soil (about $6\frac{2}{3}$ to 20 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone required
	Upland Prairie Soils								
330	Gray silt loam on tight clay	28860	3420	1250	53910	13040	7620		6630
328	Brown-gray silt loam on tight clay...	18480	2320	1080	54280	11640	5080		6160
329	Drab silt loam	35780	2420	1160	50160	8840	11520		3760
326.1	Brown silt loam on clay	54800	5120	1360	48440	11520	13920		4920
331	Deep gray silt loam	34680	3800	1320	49360	7320	7880		5760
	Upland Timber Soils								
332	Light-gray silt loam on tight clay...	9240	1620	1360	57180	13880	6920		13640
332.1	White silt loam on tight clay...	11600	1120	920	60200	10280	8120		8200
334	Yellow-gray silt loam	13760	1520	860	64420	14100	7880		1680
335	Yellow-silt loam	15890	1830	790	64480	12720	6840		14270
	Ridge Soils								
235	Yellow silt loam........	48680	5000	1340	61040	23180	9300		12940
233	Gray-red silt loam on tight clay...	29000	3480	1240	60680	14880	7760		7880
	Swamp and Bottom-land Soils								
1331	Deep gray silt loam ..	25380	2760	2184	70480	15960	12880		1720
1361	Mixed sandy loam........	31980	3060	1180	63220	10940	13220		200
1315	Drab clay....	38480	3800	1360	71320	22440	16040		40
1301	Deep peat* ...	595320	33580	1860	12380	14480	215800	449360	

THE SUBSURFACE AND SUBSOIL

In Tables 4 and 5 are recorded the amounts of plant food in the subsurface and subsoils, but it should be remembered that these supplies are of little value unless the top soil is kept rich. Probably the most important in-

*Amounts reported are from 2 million pounds of deep peat.

formation contained in Tables 4 and 5 is that all of the upland soils are even more strongly acid in the subsurface and subsoil than in the surface, thus emphasizing the importance of having plenty of limestone in the surface soil to neutralize the acid moisture which rises from the lower strata by capillary action during periods of partial drouth, which are also critical periods in the life of such plants as clover.

TABLE 5.—FERTILITY IN THE SOILS OF CLAY COUNTY, ILLINOIS
Average pounds per acre in 6 million pounds of subsoil (about 20 to 40 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone required
	Upland Prairie Soils								
330	Gray silt loam on tight clay	20600	2980	2000	88620	33690	19830		20540
328	Brown-gray silt loam on tight clay...	12060	2340	2040	87420	33540	18720		4860
329	Drab silt loam	34020	2910	1470	77160	19020	17280		16440
326.1	Brown silt loam on clay	53700	5640	1260	69660	24480	26760		13200
331	Deep gray silt loam........	24300	3540	1320	78720	17220	11040		17100
	Upland Timber Soils								
332	Light gray silt loam on tight clay...	12680	1910	1830	88110	31420	13680		47060
332.1	White silt loam on tight clay...	11640	1620	1500	91800	15540	10920		25320
334	Yellow-gray silt loam....	13230	1950	1560	96270	29310	10770		20490
335	Yellow silt loam........	15200	1720	1160	92480	20760	11880		12280
	Ridge Soils								
235	Yellow silt loam........	26880	3450	1350	95790	31410	20100		10410
233	Gray-red silt loam on tight clay...	25020	3360	1800	87720	29280	16620		27360
	Swamp and Bottom-land Soils								
1331	Deep gray silt loam....	19260	2470	2940	106300	24240	16620		6590
1361	Mixed sandy loam........	20130	2100	1350	94350	16890	14760		4350
1315	Drab clay.....	33600	3660	2040	107040	35880	25680		60
1301	Deep peat* ...	892980	50370	2790	18570	21720	323700	674040	

On soils which are subject to surface washing, including especially the yellow silt loam of the upland timber area, and to some extent the yellow-gray silt loam, and the ridge soils (and even the gray silt loam prairie on rolling areas), the supply of minerals in the subsurface and subsoil tend to provide for a low-grade system of permanent agriculture if some use is made of legume plants, as in long rotations with much pasture, because both the minerals and nitrogen are thus provided in some amount almost permanently; but where such lands are farmed under such a system not more than two or three grain crops should be grown during a period of 10 or 12 years, the land being kept in pasture most of the time; and a liberal use of limestone, as top dressings if necessary, and occasional reseeding with clovers will benefit both the pasture and indirectly the grain crops.

*Amounts reported are from 3 million pounds of deep peat

TABLE 6.—CROP YIELDS PER ACRE ON DUBOIS EXPERIMENT FIELD

On Prairie Land; Gray Silt Loam on Tight Clay

Soil treatment applied	1902 Corn bu.	1903 Oats bu.	1904 Wheat bu.	1905 Clover tons	1906 Corn bu.	1907 Oats bu.	1908 Wheat bu.	1909 Soybeans bu.
Land not Tile-drained								
None	6	9	6	1.3	30	19	1	3.5
Lime	7	16	7	1.6	35	28	8	6.7
Lime, phosphorus	13	26	25	2.4	39	44	18	8.5
Lime, phosphorus, and potassium	12	30	28	2.9	49	50	21	9.5
Land Tile-drained								
None	1	17	3	1.3	33	13	4	3.3
Lime	3	17	12	1.7	34	24	11	6.2
Lime, phosphorus	7	28	28	2.3	30	32	19	7.2
Lime, phosphorus, and potassium	14	26	32	3.0	55	44	23	10.3
Average of Two Series								
None	4	13	5	1.3	31	16	3	3.4
Lime	5	17	9	1.7	34	26	10	6.5
Lime, phosphorus	10	27	27	2.4	34	38	19	7.9
Lime, phosphorus, and potassium	13	28	30	2.9	52	47	22	9.9
Gain for lime and phosphorus	6	14	22	1.1	3	22	16	4.5
Value of increase	$2.10	$4.20	$15.40	$6.60	$ 1.05	$6.60	$11.20	$4.50
Value of crops from untreated land	$1.40	$3.40	$ 3.50	$7.80	$10.85	$4.80	$ 2.10	$3.40

RESULTS OF FIELD EXPERIMENTS AT DU BOIS

Before considering in detail the individual soil types, it seems advisable to study some of the results already obtained where definite systems of soil improvement have been given an actual trial in different parts of southern Illinois.

In Table 6 are recorded some exceedingly valuable, trustworthy, interesting and instructive data. These results were secured by eight years of actual trial on the most common type of soil in Clay County, which is also a very common type in Washington County, where the DuBois Experiment Field is located.

Anyone of common sense can understand this table if he is willing to study it.

Has tile-drainage been beneficial? There are 32 comparisons which bear upon the answer to this question,—8 with no soil treatment, 8 with lime applied, 8 with lime and phosphorus, and 8 comparisons where lime, phosphorus, and potassium were used; and the average of these results certainly does not justify investing in tile drainage for this land.

Does the application of lime and phosphorus produce benefit? The answer to this is found in the fact that the value of the eight crops on the untreated land amounted to only $37.75, whereas the value of the increase produced by lime and phosphorus was $51.65. In other words, the treat-

ment produced more than the land did, raising the crop values from $37.75 to $89.40, counting corn at 35 cents a bushel, oats at 30 cents, wheat at 70 cents, hay at $6.00 a ton, and soybeans at $1.00 a bushel, prices which are somewhat below the 10-year average. It should be stated, too, that marked improvement was made in quality (especially in wheat and clover), which is not given credit in these values.

The materials used per acre in these experiments were 5 tons of burned lime (applied only at the beginning), 1600 pounds of steamed bone meal (800 pounds for each four-year rotation), and 800 pounds of potassium sulfate (400 pounds for each rotation); but other investigations (reported in Circulars 110 and 127) have shown that ground natural limestone and fine-ground natural rock phosphate are more economical and profitable forms of lime and phosphorus; and the effect produced by potassium sulfate can also be secured at much less expense either by means of decaying organic matter (from crop residues, green manure crops, or farm manure) or by the use of less expensive soluble salts, such as kainit, as shown below. If we allow $10 for ground limestone (which would pay for the full equivalent of the lime applied) and $20 for the bone meal (its actual cost), we find that the increase produced has paid for these materials and left a net profit of $2.70 per acre per annum, or 70 percent above the cost.

Furthermore about one-half of the lime applied and at least two-thirds of the phosphorus applied still remain in the soil for the benefit of future crops.

The potassium applied during the eight years cost $20 and produced increases valued at $19.55, leaving a loss of 6 cents per acre per annum, and furthermore the potassium removed is equal to the total amount applied.

On five other plots in the DuBois field commercial nitrogen was used alone or with other elements during the first three years, but at large financial loss, and with no apparent residual effect. Since 1907, a system has been adopted for those plots which will supply both the nitrogen and organic matter by means of legume catch crops and crop residues, but another rotation will be required to get this system underway so as to produce any marked effect upon crop yields.

Owing to the severe drouth in the summer of 1908, the clover failed on the DuBois field, and consequently soybeans were substituted.

RESULTS OF FIELD EXPERIMENTS AT FAIRFIELD

The accompanying photographic reproductions show more plainly than words or figures the effect and the importance of applying limestone and phosphorus to the common upland soil of southern Illinois. These photographs were taken in 1910, and show four parts of a field which was all seeded alike to clover in 1909. This 40-acre experiment field is about one mile north of Fairfield, in Wayne County, which adjoins Clay County on the south.

The Fairfield Experiment Field is divided into four tracts of land, and a four-year rotation is practiced, consisting of corn, cowpeas (or soybeans), wheat, and clover. If the clover fails, cowpeas or soybeans may be substituted for that season; and if the winter wheat fails, oats or barley may be substituted in the spring. One half of the field, or 20 acres, is tile-drained, while the other half has only the ordinary surface drainage, as commonly

PLATE 1.—CLOVER ON FAIRFIELD EXPERIMENT FIELD, 1910. (THE FIRST CROP, SHOWN IN PHOTOGRAPHS, WAS CLIPPED AND LEFT ON THE LAND; THE SECOND CROP PRODUCED NO CLOVER SEED ON THE UNTREATED LAND, BUT $1\frac{1}{3}$ BUSHELS WERE HARVESTED WHERE THE LIMESTONE AND PHOSPHATE WERE APPLIED).

provided by plowing in rather narrow lands and keeping the middle furrows open.

Grain farming is practiced on half of the tiled land and also on half of the land not tiled; while live-stock farming is practiced on the other half of each part. A part of each of these divisions is treated with 2 tons of limestone and 1 ton of fine-ground raw rock phosphate, per acre, every four years, while another part is not so treated.

In the system of grain farming the plan is to return to the land all produce except the grain or seed, while in live-stock farming all produce (or its equivilent) is to be used for feed and bedding and the manure returned to the land in proportion to the crop yields produced during the previous rotation. It should be stated, however, that during the first rotation the manure was applied in the same amount (8 tons per acre) both where limestone and phosphate were used and where they were not used; but in the second rotation, as when manure is applied to the 1910 clover ground for the 1911 corn crop, the application of manure will be in direct proportion to the crop yields produced during the preceding four years. Thus, if the land treated with limestone and phosphate has produced as an average, one-half larger crops of corn, cowpeas, oats, and clover during 1907, 1908, 1909, and 1910, then one-half more manure will be applied to that land for the 1911 corn crop, than to the land which receives manure alone. Likewise the clover and other crop residues returned in the grain system during the second and subsequent rotations will be in proportion to the yield produced on the respective parts of the field.

Plate 2.—Clover on Fairfield Experiment Field, 1910. (The first crop, shown in photograph, made $\frac{3}{5}$ ton of foul grass with but little clover where manure alone was used, and $2\frac{2}{3}$ tons of clean clover hay where the same amount of manure was used with limestone and phosphate).

The best plan is to apply the phosphate and plow it under with manure or other organic matter; and to apply the limestone immediately after the ground is plowed for wheat in order that it may be mixed with the surface soil in the preparation of the seed-bed where clover is to be seeded the following winter or spring. However, the time and method of application are very secondary matters; the important thing is to get the limestone and phosphate on the land and well mixed with the plowed soil, altho it is better to mix one with the soil before applying the other, because when applied in intimate contact the limestone tends temporarily to lessen the availability of the phosphorus, probably by immediately neutralizing the nitric, carbonic, and organic acids produced in the decay of organic matter.

At $1.25 a ton for limestone, and $7.50 a ton for rock phosphate, the cost of those materials amounts to $10 an acre every four years; but after three or four rotations the phosphate application will be reduced to about one-half ton, which will reduce the annual expense to about $1.50 per acre, an expense which would be practically covered by an increase of 4 bushels of corn, 1½ bushels of cowpeas or soybeans, 2 bushels of wheat, 5 bushels of oats, or ¼ ton of hay.

In Table 7 are recorded the crop yields obtained since the work was begun on the land on which the 1910 clover fields are shown in the photographs. On this field clover was sown without a nurse crop late in the season of 1905, and the 1906 hay crop was mostly red top, the land having been used as a red top meadow previously.

TABLE 7.—CROP YIELDS PER ACRE ON FAIRFIELD EXPERIMENT FIELD

On Prairie Land: Gray silt Loam on Tight Clay

Soil treatment applied	1906 Clover (?) tons	1907 Corn bu.	1908 Cowpeas bu.	1909 Oats bu.	1910 Clover (?) crops
Land not Tile-drained					
Limestone and phosphorus	.50	45.4	9.0	35.7	1.50 bu.
None	.20	34.2	5.3	29.9	.00 bu.
Manure	.39	42.1	7.4	34.2	1.06 ton.
Manure, limestone, phosphorus	.48	52.4	9.4	40.9	3.50 tons.
Land Tile-drained					
Limestone and phosphorus	.12	39.0	7.7	33.0	.89 bu.
None	.10	32.1	4.7	25.8	.00 bu.
Manure	.25	35.3	5.4	30.8	.76 ton.
Manure, limestone, phosphorus	.44	49.5	11.5	37.3	3.62 tons.
Average of both Tiled and Untiled Land					
Limestone and phosphorus	.31	42.2	8.4	34.4	1.20 bu.
None	.15	33.2	5.0	27.9	.00 bu.
Manure	.32	38.7	6.4	32.5	.91 ton.
Manure, limestone, phosphorus	.46	51.0	10.5	39.1	3.56 tons.
Average gain for limestone and phosphorus	.15	10.6	3.8	6.5	1.20 bu. 2.65 tons.
Value of increase	$ .90	$3.71	$3.80	$1.95	$ 7.20 $15.90

Note.—Where no manure is applied the first cutting of clover is left on the land, the second cutting saved for seed, and the threshed clover straw returned to the land. The photographs show the 1910 fields in both the grain system and the live-stock system (first crop).

The 4-inch tile were laid in the fall and winter of 1905-1906. They were placed only four rods apart, half of the strings about 20 to 24 inches deep and the other half about 36 to 40 inches deep, and they were covered with about 4 inches of cinders before the ditches were filled. They have a satisfactory grade and a good outlet is provided. The tiled land is somewhat more nearly level than the untiled land, altho the entire field is what would be called level prairie land.

While it is very possible that, with the continued use of clover (the "best subsoiler") in the rotation, the tile drainage may ultimately prove to be a profitable investment, it is plain to see that the first requisites for the improvement of this soil are limestone, phosphorus, and organic matter.

As an average of both systems of farming on both tiled and untiled land, the increases produced by limestone and phosphorus during the first rotation have paid $10.36* an acre, or more than they cost delivered at the average railroad station in southern Illinois; and the increase in the two

*Possibly this should be increased or decreased slightly because, as hereinafter reported, on one-half of the land under experiment potassium salts are applied; and, while they produce practically no effect on the manured land, the effect is very appreciable on the unmanured land; and altho the potassium salts are applied to one-half of the check plots the same as to one-half of the land receiving limestone and phosphorus, so that the $10.36 is the actual increase produced by the limestone and phosphorus above the return from land otherwise treated the same, nevertheless there is a possibility that on part of the land represented in this summary the effect of the potassium salts was different where used with limestone and phosphorus than where used alone. No potassium salts had been applied to the land where the photographs were taken or to the land from which the reported 1910 yields of clover hay or seed were secured.

cuttings of clover hay in the first year of the second rotation has a value of \$15.90, or more than enough to pay for the second application of both limestone and phosphate, thus leaving as net profit any increases that may be produced during the next three years; and these increases will be augmented because of the larger amount of organic manures to be returned to the better yielding land. In the grain system the limestone and phosphate produced 1.20 bushels of clover seed, valued at \$7.20.

Wheat was seeded on this land in the fall of 1908, but it was winter-killed so completely that oats were seeded in the spring as a substitute. In 1908, wheat on another series of plots produced 4.1 bushels on untreated land, 13.7 bushels where limestone and phosphate had been used, 6.0 bushels where manure had been applied for corn two years before, and 18.6 bushels per acre where manure, limestone, and rock phosphate had been applied, thus showing an average increase from limestone and phosphorus of 11.1 bushels. In 1910, on still other series of plots the average increase from limestone and phosphorus was 17 1 bushels of wheat, 19 bushels of corn, and 7.7 bushels of soybeans.

ADVANTAGE OF CROP ROTATION AND PERMANENT SYSTEMS

It should be noted that the clover is not likely to be well infected with the clover bacteria during the first rotation; but even a partial stand of clover the first time will probably provide a thousand times as many bacteria for the next clover crop as one could afford to apply in artificial inoculation, for a single root tubercle may contain a million bacteria developed from one during the season's growth.

This is only one of several advantages of the second rotation over the first four years. Thus the mere practice of crop rotation is an advantage, especially in helping to rid the land of insects and foul grass and weeds. The deep-rooting clover crop is an advantage to subsequent crops because of that characteristic. The larger applications of organic manures are a great advantage; and in systems of permanent soil improvement, such as are here advised and illustrated, more limestone and more phosphorus are provided than are needed for the meager or moderate crops produced during the first rotation, and consequently the crops in the second rotation have the advantage of such accumulated residues (well incorporated with the plowed soil) in addition to the regular applications made during the second rotation. Thus, with the crop yields shown in Table 7, it is safe to say that one-fourth of the limestone and more than four-fifths of the phosphorus applied remain in the soil at the end of the first four years.

This means that these systems tend positively toward the making of rich land from poor land—toward the making of \$200 land out of \$50 land. The ultimate analyses recorded in Tables 3, 4 and 5 give the absolute invoice of these southern Illinois soils. They show that they are positively deficient only in limestone, phosphorus, and nitrogenous organic matter; and the accumulated information from careful and long-continued investigations in different parts of the United States positively establish the fact that in general farming these essentials can be supplied with greatest economy and profit by the use of ground natural limestone, very finely ground natural rock phosphate, and legume crops to be plowed under directly or in farm manure. No other applications are absolutely necessary, but, as already explained, and as shown in Table 6, the addition of some soluble salt in the beginning of a system of improvement on these soils produces some

temporary benefit, and if some inexpensive salt such as kainit is used it may produce sufficient increase to more than pay the added cost.

THE POTASSIUM PROBLEM

As reported in Illinois Bulletin 123, where wheat has been grown every year for more than half a century at Rothamsted, England, exactly the same increase was produced (5.6 bushels per acre), as an average of the first 24 years, whether potassium, magnesium, or sodium was applied, the rate being 200 pounds of potassium sulfate and molecular equivalents of magnesium sulfate and sodium sulfate. As an average of 58 years (1852 to 1909) the yield of wheat has been 12.8 bushels on untreated land, 23.3 bushels where 86 pounds of nitrogen and 29 pounds of phosphorus per acre per annum were applied; and, as further additions, 85 pounds of potassium raised the yield to 31.4 bushels; 52 pounds of magnesium raised it to 29.4 bushels; and 50 pounds of sodium raised it to 29.6 bushels. Where potassium was applied the average wheat crop removed 40 pounds of that element in the grain and straw, or three times as much as would be removed in the grain only for such crops as are suggested in Table 1. The Rothamsted soil contained abundance of limestone, but no organic matter was provided except the little in the stubble and roots of the wheat plants.

On another field at Rothamsted the average yield of barley for 58 years (1852 to 1909) has been 14.5 bushels on untreated land, 38.8 bushels where 43 pounds of nitrogen and 29 pounds of phosphorus have been applied per acre per annum; while the further addition of 85 pounds of potassium, 19 pounds of magnesium, and 14 pounds of sodium (all in sulfates) raised the average yield to 41.7 bushels, but, where only 70 pounds of sodium were applied in addition to the nitrogen and phosphorus, the average has been 43.4 bushels. Thus, as an average of 58 years, the use of sodium produced 1.8 bushels less wheat and 1.7 bushels more barley than the use of potassium, with both grain and straw removed and no organic manures returned.

While about half of the potassium, nitrogen, and organic matter, and about one-fourth of the phosphorus, contained in manure, will be lost by three or four months' exposure in the ordinary pile in the barn yard, there is practically no loss if plenty of absorbent bedding is used on cement floors, and if the manure is hauled to the field and spread within a day or two after it is produced. Again, while the animals destroy two-thirds of the organic matter and retain one-fourth of the nitrogen and phosphorus in average live-stock farming, they retain less than one-tenth of the potassium, from the food consumed; so that the actual loss of potassium in the products sold from the farm, either in grain farming or in live-stock farming, is wholly negligible on land containing 25,000 pounds or more of potassium in the surface 6⅔ inches.

The removal of one inch of soil per century by surface washing (which is likely to occur wherever there is satisfactory surface drainage) would permanently maintain the potassium in grain farming by renewal from the subsoil, provided one-third of the potassium is removed by cropping before the soil is carried away. Thus, aside from the peat soil, there is no soil in Clay County which contains less than 3,600 pounds of potassium per acre-inch. One-third of this is 1200 pounds, while 100 years of grain farming would carry away from the farm only 1275 pounds of potassium in the grain and seed of such crops as are mentioned in Table 1.

From all of these facts it will be seen that the potassium problem is not one of supply but of liberation; and the Rothamsted records show that other soluble salts have practically the same power as potassium to increase crop yields in the absence of sufficient decaying organic matter. Whether this action relates to supplying or liberating potassium for its own sake, or to the power of the soluble salt to increase the availability of phosphorus or other elements, is not known, but where much potassium is removed, as in the entire crops at Rothamsted with no return of organic residues, probably the soluble salt functions in both ways.

As an average of 84 separate tests conducted in 1907, 1908, and 1909, on the Fairfield Experiment Field, an application of 200 pounds of potassium sulfate, containing 85 pounds of potassium costing $5.10, increased the yield of corn by 7.9 bushels per acre; while 600 pounds of kainit, containing only 60 pounds of potassium and costing $4.00, gave an increase of 10.6 bushels. Thus, at 40 cents a bushel for corn, the kainit has paid for itself; but these results, like those at Rothamsted and DuBois, were secured where no adequate provision had been made for decaying organic matter.

Additional experiments at Fairfield include an equally complete test with potassium sulfate and kainit on land to which 8 tons per acre of farm manure had been applied. As an average of 84 tests with each material, the 200 pounds of potassium sulfate increased the yield of corn by .8 bushel while the 600 pounds of kainit gave an increase of 1.1 bushels. Thus, where organic manure was supplied, practically no effect was produced by the addition of either potassium sulfate or kainit; in part perhaps because the potassium removed in the crops is mostly returned in the manure if properly cared for; and perhaps in larger part because the decaying organic matter helps to liberate and hold in solution other plant food elements, especially phosphorus.

In laboratory experiments at the Illinois Experiment Station, it has been shown that potassium salts and most other soluble salts increase the solubility of the phosphorus in soil and in rock phosphate as determined by chemical analysis; also that the addition of glucose with rock phosphate in pot-culture experiments increases the availability of the phosphorus, as measured by plant growth, altho the glucose consists only of carbon, hydrogen, and oxygen, and thus contains no plant food of value.

If we remember that, as an average, live stock destroy two-thirds of the organic matter of the food consumed, it is easy to determine from Table 1 that more organic matter will be supplied in a proper grain system than in a strictly live-stock system; and the evidence thus far secured from older experiments at the University and at other places in the state indicates that if the corn stalks, straw, clover, etc. are incorporated with the soil as soon as practicable after they are produced (which can usually be done in the late fall or early spring), there is little or no difficulty in securing sufficient decomposition in our humid climate to avoid serious interference with the capillary movement of the soil moisture, a common danger from plowing under too much coarse manure of any kind in the late spring of a dry year.

If, however, the entire produce of the land is sold from the farm, as in hay farming, or when both grain and straw are sold, of course the draft on potassium will then be so great that in time it must be renewed by some sort of application. As a rule, such farmers ought to secure manure from town, since they furnish the bulk of the material out of which the manure is produced.

INDIVIDUAL SOIL TYPES

(a) UPLAND PRAIRIES

Gray Silt Loam on Tight Clay (330)

This is the predominating type of soil in the lower Illinoisan glaciation and greatly exceeds any other type in Clay County, the area being 100,720 acres, or 37 percent of the area of the county. Its topography is nearly level or gently undulating, tho in places somewhat rolling.

The type variations* are due primarily to three things: (1) the organic matter content; (2) the topography and consequent surface drainage; and (3) the depth, thickness, and density of the tight clay layer. Adjoining the somewhat rolling areas or in the vicinity of ridges, this type has received some wash that has buried the tight clay to such depths that it is less objectionable, and generally made it a better soil than the average. This is particularly noticeable in parts of Townships 3 and 4, Range 5.

In some of the low areas that grade toward drab silt loam (329), or brown silt loam on clay (326.1) the organic matter content is higher in the subsurface and subsoil, giving a better phase of the type. This fact is noticeable in certain areas in Townships 4 and 5, Range 7, and to a less extent in small areas in Township 3, Range 6.

The surface stratum, 0 to 6⅔ inches, consists of a friable, silt loam, varying from light to dark gray in color and containing sufficient clay to make it slightly plastic when wet. A few small gravels of quartz and concretions of hydrated iron oxid are sometimes found in it. The organic matter content varies somewhat from an average of 2.4 percent as determined from the total organic carbon. The surface soil is fairly pervious to water but the low organic matter content and lack of granulation render it in poor tilth, causing it to "run together" very readily from heavy rains or by freezing and thawing when wet.

The subsurface soil, averaging about 13 inches in thickness, varies from a gray silt loam to a very light gray or even white silt. The upper part of this stratum is sometimes about the same in color as the surface soil, but much oftener the plowline marks the beginning of a much lighter colored soil, which becomes still lighter with depth, passing into a distinct "gray layer," varying in thickness from 2 to 10 inches. This "gray layer" is deficient in organic matter, close-grained, very compact when dry, and quite slowly pervious to water. When saturated, it is soft, and posts may be driven very readily thru it. A few small quartz gravels and some concretions of hydrated iron oxid may be present in this stratum.

The subsoil averages about 20 inches from the surface but varies from only a few inches on the "scalds" to 2 feet or more on the best phase of the type. It is usually made up of two distinct layers, the upper tight clay, or so-called "hardpan," and a lower, friable, porous, silty layer. The former

*This type also contains many small unproductive areas known as "scalds" or "scald spots" readily recognized in a plowed field by their light color. Occasionally one of these spots may cover several acres but ordinarily these areas are only a few square rods. On these spots the ordinary surface soil, and, in many cases, the subsurface soil, is almost absent, thus bringing the subsoil to or very near the surface which constitutes the "scald". These spots are very irregular in their occurrence, some fields being entirely free from them, while in others there may be several or many. Bracted plantain (sometimes less properly called buckhorn) of stunted growth is a common plant upon these "scalds".

varies from 2 or 3 to more than 12 inches in thickness and is usually a tight, silty clay, reddish or yellowish in color, very sticky and gummy when wet and very hard when dry.

As a rule, the drainage of this type is rather poor, due to one or both of two causes, (1) the lay of the land, and (2) the tight clay subsoil. It is still a question whether it can be tile-drained profitably; but experiments now in progress will ultimately answer the question. Usually the surplus water can be disposed of fairly well by giving proper attention to surface drainage, by means of ditches and furrows.

For the economical and permanent improvement of this soil, adopt a good rotation of crops, including about one-third legume crops, plow under everything except the grain and seed (in grain farming) or make and use as much manure as possible (in live-stock farming), and apply about 1000 pounds of limestone and 200 pounds of raw phosphate, per acre, for each year in the rotation, as explained above. (Heavier initial application should be made if possible.)

Brown-Gray Silt Loam on Tight Clay (328)

This type occupies only small areas, totaling 960 acres in this county, but forms the prevailing type in the transitional area between the middle and lower Illinoisan glaciation. However, small isolated areas are found in the heart of the lower Illinoisan glaciation. With few exceptions the topography is flat or only slightly undulating.

This type contains "scalds," where the subsoil comes to the surface or injuriously near it. These are very irregular in their occurrence, some fields being devoid of them, while in others they are numerous.

The surface soil, 0 to 6⅔ inches, is a dark gray to brown silt loam, varying in color with its gradation toward other types. It contains about 2.8 percent of organic matter and has a small amount of clay and some fine sand, but medium and coarse silt predominates. It is porous, friable and easy to work.

The subsurface stratum varies much as to thickness and color. The average thickness is 10 to 12 inches altho it may be entirely absent in some places and in others 18 inches or more in thickness. It consists of a grayish brown silt loam, the color becoming lighter with depth. There is usually a distinct gray or grayish brown layer just above the subsoil, which varies in thickness from 2 to 10 inches. Where the type grades into the gray silt loam on tight clay (330) this layer may become quite well developed and partake somewhat of the impervious character of the corresponding layer in that type.

The subsoil is found at variable depths from only a very few inches on the "scalds" to 2 feet or more on the better phase of this type. It consists of two distinct layers, the upper, a plastic, gummy, yellow, drab, or dark olive-colored clay, very tight and nearly impervious to water. This stratum is from 3 to 18 inches thick and below it is a clayey silt, friable and pervious, of a yellow color or yellow with drab mottlings.

The upper layer of the subsoil is too impervious to allow good underdrainage, so that special surface drainage is commonly provided. The discussion of tile drainage for the gray silt loam on tight clay (330) applies as well to this type.

In general the same system of improvement should be adopted as for

the gray silt loam on tight clay, altho the brown-gray silt loam contains somewhat more nitrogen and phosphorus in the surface soil and less acidity in the subsoil. However, the difference in the plowed soil of an acre amounts to only about 20 loads of manure and 1 ton of phosphate, and the nitrogen is in the less active form of old humus.

Drab Silt Loam (329)

Some of the low and more poorly surface-drained areas of the prairie land have received deposits of finer material washed in from the slightly higher surrounding land, and a greater accumulation of organic matter has taken place, more particularly in the subsurface and subsoil, owing to the more luxuriant growth of vegetation and the better conditions for preventing complete decay. This has given rise to a type of soil, the drab silt loam (329) which is darker in color, better in texture, and somewhat more productive than the surrounding gray silt loam on tight clay (330), the ordinary prairie of this glaciation. The drab silt loam (329) needs under-drainage to bring it to its best condition of tilth and productiveness; and the physical composition, texture, and structure indicate that tile drainage will greatly benefit this soil, but actual field experiments are necessary to determine how satisfactorily tile will work. With the limited appropriation hitherto provided for the investigation of Illinois soils, it has not been possible for the University to establish an experiment field upon this soil type which is of very considerable importance, not only because of the 14,400 acres of this type in Clay County, but also because of its presence in most other counties in the lower Illinoisan glaciation.

The surface stratum of the drab silt loam (329) is a dark drab to brown silt loam, the former color predominating. The physical composition and texture of this soil indicate that it will work up well when thoroly drained.

The subsurface varies from a dark gray to a drab silt loam, frequently with blotches of yellow iron oxid. The amount of clay varies considerably, the stratum being very silty in some areas while in others it has sufficient clay to make it plastic, but in either case is pervious to water.

The subsoil varies in color from drab to yellowish gray with sometimes irregular blotches of all mixed together, while in physical composition it varies from a friable silt to a clay. The subsoil is rather heavy yet it is sufficiently pervious so that tile drains will very probably work well, and there are very few areas of this type that would not be greatly benefited by efficient under-drainage.

The variations of this type are due to gradations toward other types. Where it is grading toward the gray silt loam on tight clay (330) or the light gray silt loam on tight clay (332), the soil becomes lighter in color and the subsurface more silty, while the subsoil becomes lighter and less pervious to water. If the type is grading toward brown silt loam it becomes darker and slightly heavier. When drained and properly treated it promises to become one of the best types in southern Illinois, because of the absence of the gray layer and tight clay stratum in the subsurface and subsoil.

From the standpoint of fertility and methods of improvement the drab silt loam does not differ essentially from the more common gray silt loam prairie land; but with equal provisions for drainage and plant food the

drab silt loam will be a more productive soil, especially in very wet or very dry seasons, because of its more pervious character and consequent greater power to handle moisture, not only by permitting the downward flow when saturated and the upward capillary rise from the lower subsoil in time of drouth, but also because of its greater capacity for absorbing and retaining moisture; and of course it also furnishes a greater feeding range for plant roots than the less porous types.

Brown Silt Loam on Clay (326.1)

The areas of this type occur in about the same location as those of the drab silt loam (329), but have received more wash from adjoining higher land. It contains more organic matter in the subsurface and subsoil than any other upland type in the county. It is a good soil physically but, like the drab silt loam, needs under-drainage. The total area in the county is only 824 acres.

The surface soil is a dark brown to black silt (or clayey silt) loam, rather plastic when wet, but somewhat granular under proper conditions for granulation.

The subsurface stratum differs from the surface in having a slightly lighter color and containing more clay, there being sufficient to render it quite plastic.

The subsoil is a brownish or dark drab silty clay somewhat impervious but probably susceptible of satisfactory drainage. While tile will probably not draw as far in this type or in the drab silt loam (329) as in some corn belt types, yet by putting the lines of tile from four to eight rods apart this land could all be well drained, so far as can be judged from physical characteristics.

The nitrogen content of the subsurface and subsoil is naturally higher because it is one of the constituents of the organic matter, but such organic nitrogen, particularly in those strata, becomes available too slowly to be a factor of great significance; and, like the other types already described, the essential requirements for the improvement of this soil are limestone, phosphorus, and nitrogenous organic matter.

Deep Gray Silt Loam (331)

This type occurs in low, poorly drained areas that have received a considerable amount of material washed from the surrounding higher lands, but the material deposited contains less clay than that received by the previously described types of similar topography.

The surface soil is a gray to dark gray silt loam, under which to a depth of 40 inches is a gray silt loam or gray silt that differs from the surface chiefly in having a lighter color. Locally a stratum of clayey silt may be developed at about 36 inches in depth. This soil will certainly underdrain, and when drained will become very productive with proper treatment.

As will be seen from Tables 3, 4, and 5, this type averages about as high in acidity and rather lower in plant food than any of the other prairie types. The greater porosity and deeper feeding range for plants are distinct advantages; but the same systems of improvement should be followed.

(b) TIMBER UPLANDS

Light Gray Silt Loam on Tight Clay (332)

This type occurs in old timbered regions where the land is so nearly level that there is no chance for rapid surface drainage. The type was originally the same as the gray silt loam on tight clay (330) but has a lower organic matter content because of the long-continued growth of timber. The upland soils that were timbered for centuries have less organic matter and are consequently much lighter in color than the adjoining prairie because of the fact that forest trees add very little organic matter to the soil whereas the process of decomposition is going on more or less rapidly in all soils. The leaves and twigs of the trees fall upon the surface of the ground and decay completely; whereas the prairie grasses form a mass of roots in the soil which, when they die, are prevented from complete decay by the absence of sufficient oxygen. In this way prairie grasses and other plants cause a gradual accumulation of organic matter. If prairie land becomes forested the organic matter is slowly diminished to a low point. The average amount of organic matter in the upland timber soils of the state is 2 percent while the prairie soils have 5.3 percent, the corn belt soils being included in both cases. Some of the level timber soils are so depleted in this constituent that they do not have over 1 percent in the surface stratum.

This type has two distinct phases, one a slightly better surface-drained but lighter colored, and less productive, and the other the more swampy areas (where water oaks commonly grew), a darker surface and more porous soil, so that better drainage is probably possible. The amount of this latter phase is small as compared with the former and is frequently confined to narrow strips too small to map.

"Scalds" are found upon this type but are not so common as upon the gray silt loam on tight clay (330) or brown gray silt loam on tight clay (328).

The surface soil of the most common level timber land (332) of this glaciation is a light gray to almost white silt loam containing about 1½ percent of organic matter. It is somewhat porous and incoherent but contains sufficient clay to bake when puddled and dried. When the moisture content is at its optimum it works very well, but because of the low organic matter content it is "run together" badly by rains or by freezing and thawing when wet. This layer as well as the subsurface and subsoil contains large numbers of iron oxid concretions of various sizes up to one-fourth inch in diameter. Small pebbles of quartz are sometimes found, possibly having been brought to the surface from the underlying glacial till by burrowing animals during past centuries.

The subsurface varies from a light gray silt loam to a white silt, compact but friable, from 2 to 20 inches in thickness. Water passes thru it slowly.

The subsoil consists of a compact yellowish gray clayey silt or silty clay, only slowly pervious to water, but usually not quite so tight as the corresponding layer of the gray silt loam on tight clay (330). In places the type has a somewhat more friable subsoil and is not so impervious as the above, and where the tight clay occurs at the greater depths from the surface it is less objectionable.

The invoice of plant food shows great need of nitrogen and phosphorus, and, with these and a liberal use of limestone and organic matter, the soil can be made highly productive with proper surface drainage.

White Silt Loam on Tight Clay (332.1)

This type is found on the level upland and is or has been covered by a growth of stunted trees principally the so-called post oak. The term post-oak flat or post-oak soil is commonly applied to this type altho these terms are often applied locally to the poorer phase of light gray silt loam on tight clay (332). The surface drainage is very poor and the subsoil is almost impervious. The total mapped area in the county, is only 224 acres, but there are many small areas of this type that cannot be shown on the map, and much of the light-gray silt loam on tight clay (332) grades toward this related type (332.1).

Where the type has been cultivated, the surface soil is a white silt, while in the timbered areas there may be an inch or two of dark gray silt loam underlain by the characteristic white silt. The organic matter content is even lower than in the preceding type. Because of this and the high silt content, the soil "runs together" badly. Iron oxid concretions are always present.

The subsurface layer is a white silt with many iron oxid concretions. The thickness varies from 4 to 16 inches, passing abruptly into the subsoil which is a light yellow, iron-stained silty clay, very tough and plastic when wet and hard when dry. Both subsurface and subsoil are almost impervious and when these layers are dry water moves down into them with extreme slowness.

In nitrogen and phosphorus this is one of the poorest soils found in the state, the total in the surface soil 6⅔ inches deep being about equal to the needs of three rotations in nitrogen and of five rotations in phosphorus, with such crops as are suggested in Table 1; and with no provision to make plant food available the crops produced on this type are often not worth raising. With liberal use of limestone, phosphorus, and organic matter this soil can be markedly and profitably improved where the surface drainage is adequate; but, like all soils with tight clay subsoils, it will not be a good soil for very wet or very dry seasons.

Yellow-Gray Silt Loam (334)

This type lies between the yellow silt loam (335), on the one hand, and the gray silt loam on tight clay (330) or light gray silt loam on tight clay (332), on the other, and it is somewhat intermediate in character. For general agricultural purposes it is one of the best types of soil in the county, provided it exists in large areas; whereas small areas are sometimes almost valueless because of scald spots.

The common topography is undulating but varies from nearly level to almost broken land. The slopes are rather long and gentle, but in places very short abrupt slopes of yellow silt loam occur which are too small in area to show separately on the map. The surface drainage is generally good, in fact so good that there is considerable washing going on where the methods of culture are not the best for preventing it. While this type was generally timbered, it sometimes extends out into the prairie along natural drainage channels and as these particular areas represent recent erosion of the prairie, it shows "scalds" or tight clay outcrops, the presence of which renders these narrow areas very inferior to the type generally, and in some places almost worthless. These numerous "scald" areas are rarely over two or three acres

in extent and more frequently only a fraction of an acre, often occurring as narrow strips along the stream or draw.

The total area of yellow-gray silt loam is 21,240 acres, or 7.09 percent of the total area of the county.

Since the type is a transitional form between other types, the surface soil varies a great deal. The predominating phase is a yellowish or grayish yellow silt loam, but the type varies from that to a gray silt loam as it grades toward the gray and the light gray silt loam on tight clay (330 or 332), or to yellow silt loam as it passes into the eroded type (335).

In physical composition, it contains some fine sand and locally, in small areas, quite appreciable amounts, but the prominent constituent is silt of various grades. The soil is deficient in organic matter, there being only 1½ to 2 percent present. The surface soil is porous and friable but "runs together" badly because of its shortage in organic matter.

The subsurface, like the surface, varies from a yellowish gray to yellow silt loam sufficiently porous to permit percolation, and the physical composition is such as to allow ready capillary movement. The thickness of the subsurface stratum varies from a few inches to about 16 inches.

The subsoil is a yellow or mottled grayish silt or clayey silt, somewhat compact but pervious. The depth to the subsoil is quite variable owing to the amount of washing that has taken place. In places the surface and subsurface have been entirely removed, but this is unusual, and the depth to the subsoil varies commonly from 10 to 20 inches.

With good farming and a liberal use of limestone, phosphorus, and legumes, this soil can be profitably improved until it will produce larger crops than the present average of the $200 corn belt land, which, of course, will just as certainly lose its high productive power if the common agricultural practice of the corn belt is continued, with no adequate return to the soil for the large amounts of plant food removed in crops.

Yellow Silt Loam (335)

This type includes the broken, very rolling, and hilly land along the streams and sometimes on the steep slopes of ridges. It is of such a steeply sloping character that much of it should never have been put under cultivation. When properly treated it makes excellent pasture land, and much of it should be kept forested. When cultivated the utmost care should be taken to prevent washing as this is the most serious danger to this type of soil. Already many fields have been ruined by gullying. In Clay County it covers an area of 41,760 acres, or 14 percent of the total.

The surface soil is a friable yellow silt loam varying somewhat with topography, the less broken being grayish yellow while the steep slopes are reddish yellow, or brownish yellow where a little more organic matter remains. As a rule, the soil has enough fine sand for fairly good texture, but it is very deficient in organic matter and this condition contributes toward its excessive washing. "Clay points", or places where the top soil has been removed by washing, are quite common and they are very unproductive.

The subsurface varies but is from 6 to 14 inches thick where little or no washing has taken place. It consists usually of a friable yellow slightly loamy silt mottled with gray or with reddish blotches of iron oxid.

The subsoil is usually a somewhat friable and quite pervious yellow clayey silt. Where much washing has occurred the glacial drift frequently forms the subsoil.

Where soil improvement is attempted, large use should be made of limestone and legumes. Limestone may be applied as a top-dressing even on permanent pastures, and some clover can usually be introduced into the pasture herbage by mixing the clover seed with much limestone and some dry soil containing clover bacteria, and sowing with a sharp disk drill with fertilizer attachment, thus placing the inoculated clover seed in the soil itself and in contact with the limestone. As a rule it is not advisable to apply phosphorus to this soil except where ample provision is made for increasing the organic matter and nitrogen and for preventing loss by erosion; and the phosphorus should not be used as a top-dressing, but thoroly mixed with the plowed soil before seeding down to grass and clover.

(c) Ridge Soils

Yellow Silt Loam (235)

The morainal and preglacial ridges of the lower Illinoisan glaciation have given a slight variation to the usual level topography of this region. These have been covered with from 8 to 15 feet of loess and this, together with the excellent drainage, has resulted in the formation of a soil very different from the surrounding prairie but somewhat resembling in texture the better phase of the yellow silt loam timber land (335), already described. The total area of the type is 2560 acres. The ridges upon which this type occurs vary from 20 feet to 100 feet or more in height.

The surface soil is a yellow or yellowish-brown silt loam with considerable very fine sand. The color varies with the amount of erosion that has gone on. Where little washing has occurred the color may be a yellowish brown, while with more washing it will become yellow. The soil is loose, porous, readily pervious to water and its physical composition is such as to give it great water-retaining power and strong capillarity so that it will resist drouth well. The organic matter content is about 3½ percent.

The subsurface layer, 6⅔ to 20 inches, varies from a yellowish brown silt loam to a yellow silt or slightly clayey silt. It becomes more compact with depth but still retains its perviousness and capillary power.

The upper part of the subsoil is somewhat compact and slightly clayey but passes into a friable silt containing some fine sand. It is yellow or reddish-yellow in color. Below 24 inches it may be slightly gray or marked with gray blotches, and when grading toward yellow-gray silt loam (334) may become decidedly gray. This soil, considered from a physical standpoint, is about as good as could be desired. Its organic matter content should be maintained and even increased in order to prevent destructive washing. It is a well-aerated, well-drained soil and will withstand drouth well, and in those respects it is decidedly the best upland type in the county.

It also contains a fair amount of plant food, exceeding in its nitrogen content all other upland types and even the extensive bottom lands. Nevertheless it is plain to see that nitrogen and phosphorus are the limiting elements in this as well as in most other soils of the county; and with the well developed acidity of the subsurface and subsoil, the essential requirements for its improvement are the same; namely, a liberal use of limestone, phosphorus, and legume crops in a good rotation, the legumes and at least the coarse product of the other crops being returned to the soil either directly

or in manure. By these means this soil can readily be made to produce crop yields equal to those of the best soils in the state. It is especially well adapted for alfalfa when well treated with limestone and manured and inoculated to give the alfalfa a good start.

Gray-red Silt Loam on Tight Clay (233)

This type of soil occurs on the low ridges, which are in part at least of preglacial origin, varying from 5 to 75 feet above the surrounding upland. As a rule, it is one of the poorest upland types in the state, but the areas in this county are usually a better phase of the type. It comprises 9180 acres, or 3 percent of the area of the county. The surface drainage is usually good, and in some places the type may suffer from erosion; but it is extremely doubtful whether tile-drainage will profitably benefit this soil, at best not until other methods of improvement have been put into practice.

The surface soil is a friable gray silt loam very similar to that of the gray silt loam on tight clay (330), and the subsurface layer resembles the corresponding one in the above type both in texture and thickness but contains more of the higher oxid of iron, giving it a reddish color.

The subsoil varies in depth from 7 to 20 inches from the surface and consists of a layer of plastic, gummy, impervious red clay varying from 4 to 12 inches thick and underlain by a less plastic and more silty stratum. When dry the red clay becomes so hard that it is next to impossible to bore into it with an auger. Where this layer becomes the surface soil, which it does on some small eroded areas, the soil is practically worthless.

In plant food content this soil is almost a perfect duplicate of the gray silt loam on tight clay, not only in the surface, but likewise in the subsurface and subsoil; but with its tighter texture and more rolling topography, more erosion and less leaching have occurred, and consequently it has retained more acidity and somewhat more of the abundant mineral elements. Methods for improvement are, of course, the same as for the more extensive gray silt loam on tight clay.

(d) BOTTOM LANDS

Deep Gray Silt Loam (1331)

This type occurs along most of the streams of the lower Illinoisan glaciation. The material from which it is formed comes from the gray, yellow-gray, and yellow silt loams of the upland, and has a gray or yellowish gray color. It overflows during floods and in most places still receives frequent or occasional deposits of new material. If we disregard the difficulties from overflow and of drainage, this is the most valuable important soil type in the county.

There is in the county a total area of 31,680 acres of this type. It lies so low that the drainage is generally poor and there is often much difficulty in getting sufficient outlet for under-drainage or sometimes even for adequate surface drainage. Where a satisfactory outlet can be secured tile drainage greatly benefits this soil.

The surface soil is a gray silt loam varying from a light drab to drab in color and from a loam to a clayey silt loam in physical composition. The subsurface and subsoil are about the same as the surface except lighter in

color and commonly a little more clayey with depth. In the smaller stream bottoms the recent deposits are frequently yellow and consequently there may be a stratum of yellow on the gray varying from a few inches to a foot or more in thickness.

In phosphorus content this soil slightly exceeds the most common prairie soil of the corn belt, and the porous subsoil affords such a deep feeding range that the application of that element is not likely to give profitable returns, except where overflow is not common and where the soil has been long cropped.

The soil is moderately acid and rather poor in nitrogen, altho this percentage deficiency is counterbalanced to a large extent by its great depth and porosity.

While the overflow and drainage problems are of first importance, where these are under sufficient control to permit of soil improvement the use of limestone and the addition of nitrogenous organic matter, as by plowing under clover or manure, will make this soil still more productive; and, if protected so as to prevent the usual overflow deposits, the addition of phosphorus will ultimately be necessary, and is likely to be very profitable for the highest improvement of the soil. To illustrate it may be pointed out that on the University farm at Urbana, land which has yielded 65 bushels of corn per acre as a six-year average, in a rotation of corn, oats, and clover, where limestone and organic manures have been provided, has with the addition of phosphorus made an average of 87 bushels during the same years. Thus there may be room for phosphorus "at the top", even where very satisfactory yields may be secured without its application and where other factors are of first importance.

Mixed Sandy Loam (1361)

This type occurs chiefly in the bottom lands of the smaller streams and principally in the northwest part of the county, where its greater prevalence is probably due to the presence in that section of a deposit of sandstone which frequently outcrops along the streams. The breaking down of this sandstone, together with the small amount washed in from the upland, furnishes sufficient sand to form the type. Practically all of it is subject to overflow. It varies greatly in physical composition which in places is changed more or less with each flood.

The surface soil is a brown, yellowish brown, or yellowish gray sandy loam. It is very pervious to water but usually has enough of the finer soil constituents to make it sufficiently retentive of moisture to grow good crops. All grades of sand are present but the coarse and medium predominate. In small areas it varies in physical composition from loam to sand. The organic matter content also varies, but averages about 2½ percent.

The subsurface is a sandy loam, lighter in color than the surface, often becoming more sandy with depth and usually passing into a coarse yellow or yellowish gray sand subsoil.

The content of sand and the depth to the sand subsoil varies with the topography, the higher places being more sandy, while the low areas are more silty and more variable in the subsoil. The soil is very productive except on very sandy spots, which are sometimes present but not large enough to map.

Because of their open character sand soils are aerated to much greater depths than soils in which silt or clay predominate and because of this a much

larger amount of plant food is made available even though the sand soil may be no richer in the important elements. Thus with the same content of nitrogen and phosphorus as the gray silt loam prairie, the sand soil will produce twice as large crops, because the aeration and feeding range is at least twice as great. The acidity of the sand soil is slight. Where it is subject to frequent overflow it is doubtful if any applications will prove profitable, but where overflow is not common both limestome and manure may well be used in preparing the soil for alfalfa for which it is well adapted if the drainage is good.

Drab Clay (1315)

The total area of this type in the county comprises 25 acres situated in the bottom land near the Little Wabash River in an area adjoining the deep peat (1301). It is a common type in old bayous along the Mississippi, Kaskaskia, and Wabash Rivers, occurring in the low, poorly drained areas, chiefly former stream channels, now partly filled with the finest sediment. The surface soil is a dark drab, granular, plastic clay. The subsurface and subsoil are lighter in color than the surface but also consists of plastic clay. The type is difficult to work, especially if not well drained, the common condition.

It is a neutral soil and fairly well supplied with plant food. The one area found in the county is only a few inches above the usual level of the ground water. It has never been cropped and probably never will be unless it is included in some future extensive drainage district in which the general level of the Little Wabash River should be lowered so as to provide an outlet for such low-lying bottom lands.

Deep Peat (1301)

This type is found in a single small area of only 15 acres where springs abound (Section 3, Township 3, Range 8), and the type represents the accumulation of vegetation formed by the growth of grasses, sedges, mosses and other plants. The surface of the peat is only a few inches above the water level, and as an outlet for adequate drainage could be provided only at great expense (or in connection with an extensive drainage system), the utilization of this area for anything but pasture is quite impracticable at present. The samples show considerable carbonate present, principally as fragments of shells.

This soil contains about 50 percent of organic matter and more than 20 percent of limestone. If it could be obtained in dry condition so as to reduce the expense of hauling, it could be used with some profit as a fertilizer on the acid upland soils in the neighborhood, which, as a rule, are also markedly deficient in nitrogen and organic matter. The addition of a small application of manure or some clover turned under would hasten the decomposition of the peaty material and thus greatly increase its value when used as a fertilizer. (It should be noted that the specific gravity of peat soil is only about one-half that of normal soil; and consequently an acre of peat soil 6⅔ inches deep weighs, in the dry condition, 1 million pounds, while ordinary soils weigh 2 million pounds for the same stratum.)

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

SOIL REPORT NO. 2

MOULTRIE COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER,
J. H. PETTIT, and J. E. READHIMER

URBANA, ILLINOIS, JUNE, 1911

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MOULTRIE COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER, J. H. PETTIT, and J. E. READHIMER

Introduction

About two-thirds of Illinois lies in the corn belt, where most of the prairie lands are black or dark brown in color. In the southern third of the state the prairie soils are largely of a gray color, and this region is better known as the wheat belt, altho wheat is often grown in the corn belt and corn is also a common crop in the wheat belt.

Moultrie County, representing the corn belt; Clay County, which is fairly representative of the wheat belt; and Hardin County, which is taken to represent the unglaciated area of the extreme southern part of the State, have been selected for the first Illinois Soil Reports by counties. While subsequent County Soil Reports will be sent only to the residents of the county concerned (and to anyone else upon request), these first three are sent to the Station's entire mailing list within the State.

Each county report is intended to be as nearly complete in itself as it is practicable to make it, and even at the expense of some repetition, each will contain a general discussion of important fundamental principles to help the farmer and landowner to understand the meaning of the soil fertility invoice for the lands in which he is interested. In Soil Report No. 1, "Clay County Soils," this discussion serves in part as an introduction, while in this and other reports it will be found in the Appendix, but if necessar" it should be read and studied in advance of the report proper.

Soil Formation

Moultrie County lies wholly within the Early Wisconsin Glaciation, but near its southern border. While it has no very distinct morainal ridges, yet the county is covered to an average depth of more than 200 feet with a deposit of glacial drift consisting generally of a mixture of clay, silt, sand, gravel, and boulders. This drift consists of the Illinoisan below and the Wisconsin above, separated by the Iowan loess carrying the old Sangamon soil. Covering the Wisconsin drift to a depth of three to six feet or more is another layer of fine-grained, loessial or wind-blown material from which the present soil has been formed. This has been modified to a considerable degree by different conditions and agencies, such as the growth of grasses, of timber, washing and drainage, which have given rise to the different soil types found in the county.

TABLE 1. SOIL TYPES OF MOULTRIE COUNTY

Soil Type No.	Names	Area in sq. mi.	Area in acres	Percent of total
	(a) Upland Prairie Soils (Page 20)			
1126	Brown silt loam	264.42	169,229	77.52
1120	Black clay loam	15.42	9,869	4.52
	(b) Upland Timber Soils (Page 23)			
1132	Light gray silt loam on tight clay	4.75	3,040	1.39
1134	Yellow-gray silt loam	35.05	22,432	10.28
1135	Yellow silt loam	2.19	1,402	.64
	(c) Swamp and Bottom-land Soils (Page 25)			
1454	Mixed loam	13.72	8,781	4.02
	(d) Terrace Soil (Page 26)			
1554.6	Mixed loam over sand or gravel	5.51	3,526	1.61
	Totals	341.06	218,279	100.00

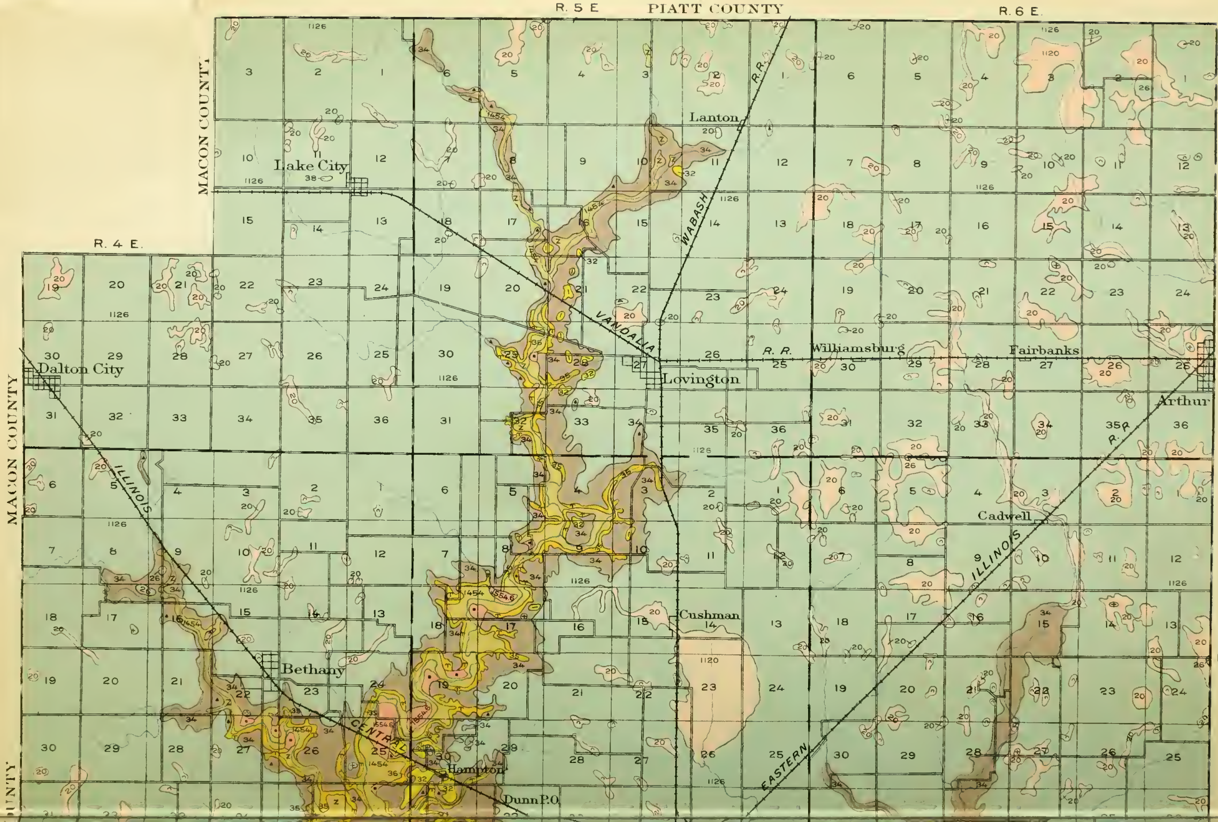
The only soil type in the county which includes non-tillable land is the yellow silt loam, whose topography is often so steeply sloping that it ought to be kept in forest or at least almost continuously in pasture. Of course, much of the swamp and bottom land needs more adequate drainage, which is very difficult, if not impracticable, to provide as yet in some places.

THE INVOICE AND INCREASE OF FERTILITY IN MOULTRIE COUNTY SOILS

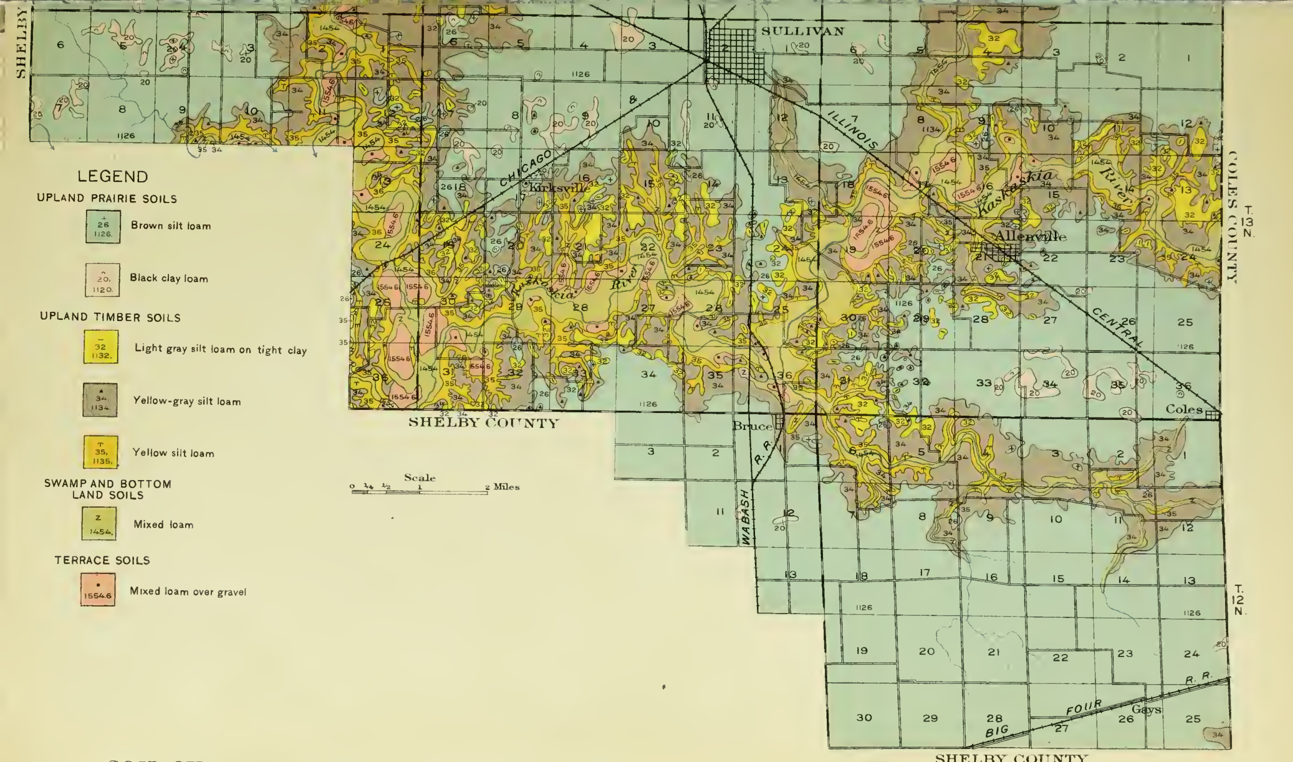
SOIL ANALYSIS

In order to avoid complication and confusion in the practical application of the technical information contained in this report, the results are given in the most simplified form. The composition reported for a given soil type is as a rule the average of many analyses, which, like most things in nature, show more or less variation. For all practical purposes the average is most trustworthy and sufficient, as will be seen from Bulletin 123, which reports the general soil survey of the state, and in which are reported many hundred individual analyses of soil samples representing twenty-five of the most important and most extensive soil types in the state.

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but the rate of liberation is governed by many factors, as explained in the Appendix. As there stated, probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even though plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that the productive power of normal soil in humid sections depends primarily upon the stock of plant food contained in the soil and upon the rate at which it is liberated.



PIATT COUNTY
R. 5 E
R. 6 E.
R. 4 E.
MACON COUNTY
DOUGLAS COUNTY
T. 15 N.
T. 14 N
Lanton
Lake City
Lovington
Williamsburg
Fairbanks
Arthur
Dalton City
Cadwell
Cushman
Bethany
Hampton
Dunn P.O.
WABASH R. R.
VANDALIA R. R.
ILLINOIS CENTRAL
ILLINOIS EASTERN R.



SOIL SURVEY MAP OF MOULTRIE COUNTY
UNIVERSITY OF ILLINOIS AGRICULTURAL EXPERIMENT STATION

The fact may be repeated, too, that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all plants, only one (hydrogen) from water, and seven from the soil, altho nitrogen, one of these seven elements secured from the soil by all plants may also be secured from the air by one class of plants (legumes), in case the amount liberated from the soil is insufficient; but even these plants (which include only the clovers, peas, beans, and vetches among our common agricultural plants) secure only from the soil six elements (phosphorus, potassium, magnesium, calcium, iron and sulfur) and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Table A, in the Appendix, shows the requirements of large crops for the five most important plant food elements which the soil must furnish. (Iron and sulfur are supplied normally in sufficient abundance, compared with the amounts needed by plants, so that they are not known ever to limit the yield of crops.)

In Table 2 is recorded the invoice of the plowed soil, showing the total amounts of these five elements of plant food contained in each of the different types of soil in Moultrie County.

TABLE 2.—FERTILITY IN THE SOILS OF MOULTRIE COUNTY, ILLINOIS
Average pounds per acre in 2 million pounds of surface soil (about 0 to 6⅔ inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone required
	Upland Prairie Soils								
1126	Brown silt loam	52260	4810	980	36020	8650	10430		80
1120	Black clay loam (normal phase).	72280	6480	1810	35260	14830	20460	8350	
1120	Black clay loam (lighter phase).	52600	6940	1320	32120	15080	18560	760	
	Upland Timber Soils								
1132	Light gray silt loam on tight clay.....	19810	1680	600	35080	6350	7390		120
1134	Yellow gray silt loam......	28170	2310	680	36150	6040	6370		180
1135	Yellow silt loam	19260	1580	480	36960	6220	5180		320
	Swamp and Bottom-land Soils								
1454	Mixed loam (normal phase)	41940	4180	1260	41740	9820	13000	780	
1454	Mixed loam (lighter phase)	24420	2600	620	37040	8520	13000	7780	
	Terrace Soil								
1554.6	Mixed loam over sand or gravel	11940	1300	500	34860	5460	6300		40

These data represent the total amounts of plant food found in two million pounds of the surface soil, which corresponds to an acre of soil about 6⅔ inches deep, including at least as much soil as is ordinarily turned with

the plow, and representing that part of the soil with which we incorporate the farm manure, limestone, phosphate, or other fertilizer applied in soil improvement. This is the soil stratum upon which we must depend in large part to furnish the necessary plant food for the production of the crops grown, as will be seen from the information given in the Appendix. Even a rich subsoil has little or no value if it lies beneath a worn-out surface, but if the fertility of the surface soil is maintained at a high point then the strong and vigorous plants will have power to secure more plant food from the subsurface and subsoil than would be the case with weak, shallow-rooted plants.

By easy computation it will be found thát the most common prairie soil of Moultrie County does not contain enough total nitrogen in the plowed soil for the production of maximum crops for ten rotations; while the upland timber soils contain as an average less than one half as much nitrogen as the prairie land.

Practically the same condition obtains with respect to phosphorus, nine-tenths of the soil area of the county containing no more of that element than would be required for twelve crop rotations if such crop yields were secured as suggested in Table A of the Appendix; and in case of the cereals it will be seen that about three-fourths of the phosphorus taken from the soil is deposited in the grain, while only one-fourth remains in the straw or stalks.

On the other hand, the potassium is sufficient for 2,800 years, if only the grain is sold, or for 450 years even if total crops were removed and nothing returned. The corresponding figures are about 2,100 and 500 years for magnesium, and about 10,000 and 250 years for calcium.

Thus, when measured by the actual crop requirements for plant food, potassium is no more limited than magnesium and calcium and, as explained in the Appendix, with these elements we must also consider the heavier loss by leaching.

These general statements relating to the total quantities of plant food in the plowed soil certainly emphasize the fact that the supplies of some of these necessary elements of fertility are extremely limited when measured by the needs of large crop yields for even one or two generations of people.

The variation among the different soil types with respect to their content of important plant food elements is also very marked. Thus, the prairie soils contain from three to four times as much nitrogen as the timber lands of the same topography; and the normal black clay loam, the richest prairie land, contains about three times as much phosphorus as the upland timber soils.

On the other hand, the most significant fact revealed by the investigation of Moultrie County soils is the low phosphorus content of the common brown silt loam prairie, a type of soil which covers more than three-fourths of the entire county. The market value of this land is about $200 an acre, and yet an application of $30 worth of fine-ground raw rock phosphate would double the phosphorus content of the plowed soil. Such an application properly made would also double the yield of clover in the near future; and, if the clover were then returned to the soil either directly or in farm manure, the combined effect of the phosphorus and nitrogenous organic matter with a good rotation of crops would soon double the yield of corn on most farms.

The average yield of corn of Moultrie County for the ten years, 1901 to 1910, is 34.7 bushels per acre;* yet this county occupies the most favored position in the most southern lobe of the corn belt of the United States. Meanwhile, Boone County, on the Wisconsin line, nearly 200 miles farther north, has averaged 40.5 bushels of corn per acre during the same ten years.

With nearly 5,000 pounds of nitrogen in the soil and an inexhaustible supply in the air, with 36,000 pounds of potassium in the same soil and with practically no acidity, the economic loss of farming such land with less than 1,000 pounds of total phosphorus in the plowed soil can only be appreciated by the man who fully realizes that the crop yields could be doubled by adding phosphorus,—and without change of seed or season and with very little more work than is now devoted to the fields.

Fortunately, some definite field experiments have already been conducted on this same type of soil in different counties in the same soil area as Moultrie (the Early Wisconsin Glaciation), as at Urbana in Champaign County, at Sibley in Ford County, and at Bloomington in McLean County.

RESULTS OF FIELD EXPERIMENTS AT URBANA

A three-year rotation of corn, oats, and clover was begun on the North Farm at the University of Illinois in 1902, on three fields of typical brown silt loam prairie land which, after twenty years or more of pasturing, had grown corn in 1895, 1896 and 1897 (when careful records were kept of the yields produced), and had then been cropped with clover and grass on one field, oats on another, and oats, cowpeas and corn on the third field, till 1901.

As an average of the three years, 1902-1904, phosphorus increased the crop yields per acre by .68 ton of clover, 8.8 bushels of corn, and 1.9 bushels of oats.

During the second three years, 1905-1907, phosphorus produced average increases of .79 ton of clover, 13.2 bushels of corn, and 11.9 bushels of oats.

The third course of the rotation, 1908-1910, the average increases produced by phosphorus were 1.05 tons of clover, 18.7 bushels of corn, and 8.4 bushels of oats.

For convenient reference the results are summarized in Table 3.

TABLE 3.—EFFECT OF PHOSPHORUS ON BROWN SILT LOAM
(Average increase per acre)

Rotation	Years	Corn	Oats	Clover tons	Value of increase	Cost of treatment*
		Bushels				
First....	1902, 3, 4	8.8	1.9	.68	$ 7.73	$7.50
Second	1905, 6, 7	13.2	11.9	.79	12.93	7.50
Third.............	1908, 9, 10	18.7	8.4	1.05	15.37	7.17

*Prices used are 35 cents a bushel for corn, 30 cents for oats, $6.00 a ton for clover hay, 10 cents and 3 cents a pound for phosphorus in bone meal and rock phosphate, respectively.

As an average the well treated land has produced about 90 bushels of corn, 60 bushels of oats, and 2½ tons of hay per acre. These crops would remove about 130 pounds of phosphorus in the nine years, while 300 pounds

*Statistical Report, Illinois State Board of Agriculture, December 1, 1910, page 39.

PLATE 1. CORN ON URBANA EXPERIMENT FIELD
LEGUME CROPS AND CROP RESIDUES PLOWED UNDER
LIMESTONE APPLIED

were applied (in bone meal and in rock phosphate, as explained below), so that the average phosphorus content of the plowed soil has been increased from about 1,100 in 1901 to 1,300 pounds per acre in 1910, about 30 pounds having been returned, as an average, in the organic manures described below.

Meanwhile the untreated land has lost about 100 pounds of phosphorus, corresponding to a reduction from 1,100 to 1,000 pounds.

As shown in Table 3, the phosphorus paid its cost the first rotation, and the third rotation it paid more than twice its cost, besides leaving the treated soil about one-third richer in phosphorus than the untreated soil.

During the first six years, 1902-1907, phosphorus was applied at the rate of 25 pounds per acre per annum in 200 pounds of steamed bone meal, 600 pounds of bone usually being applied once every three years on the clover sod and plowed under for corn. For the last rotation, 1908-1910, the 600 pounds of steamed bone were applied on one-half of each plot, and 1,800 pounds of fine-ground raw rock phosphate on the other half. The bone

PLATE 2. CORN ON URBANA EXPERIMENT FIELD
LEGUME CROPS AND CROP RESIDUES PLOWED UNDER
LIMESTONE AND PHOSPHORUS APPLIED

costs about $25 a ton (10 cents a pound for 250 of phosphorus), and the raw phosphate about $7.50 per ton (3 cents a pound for 250 of phosphorus).

As an average of the last three years one dollar invested has paid back $2.38 from bone meal and $2.39 from raw rock phosphate in the value of the increase; and, of course, the reserve supply of phosphorus is much greater where the rock phosphate is used.

In 1910 the respective increases in yield from bone meal and rock phosphate were 15.2 and 19.6 bushels of corn, 11.9 and 12.8 bushels of oats, and 1.33 and 1.37 tons of clover hay, the larger increase being produced by the raw rock phosphate with every crop, in harmony with the cumulative effect to be expected from the increasing store of phosphorus in the soil.

As a rule, each increase given in Table 3 represents the average of duplicate tests over a period of three years. These averages are considered trustworthy, excepting, perhaps, some results on oats, due to abnormal seasons. Normally the oat crop shows a gradually increasing effect from the use of phosphorus. (The increase for oats in 1910 was 13.8 bushels in grain farming and 11 bushels in live-stock farming.)

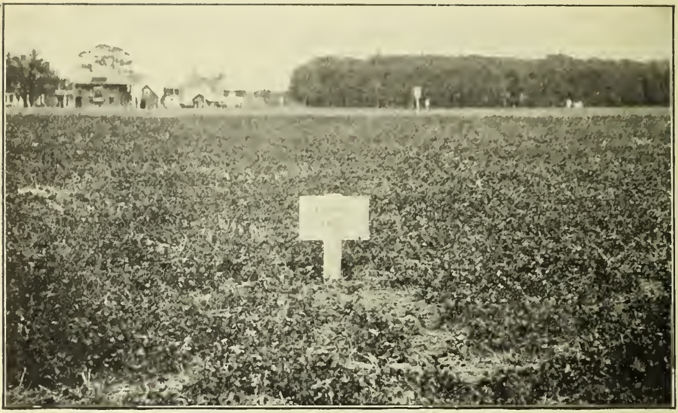


PLATE 3. CLOVER ON URBANA EXPERIMENT FIELD
LEGUME CROPS AND CROP RESIDUES PLOWED UNDER
LIMESTONE APPLIED

The duplicate tests each year correspond to the two systems of farming adopted on these fields, one of which is a grain system in which the nitrogen and organic matter are maintained or increased by returning to the land all crop residues left after the grain or seed is sold. These residues include the corn stalks, straw, and all clover except the seed. This system in complete form has been practiced only during the last three years, 1908-1910, and consequently corn has not yet been grown on land where the corn stalks had been returned to the soil.

In the other system, known as live-stock farming, the crops are all harvested and used for feed and bedding, and as many tons of average manure are applied as the total number of tons of air-dry produce from the respective plots. This system in complete form has been followed only during the last six years, 1905-1910.

By computation from data reported in the Appendix, it can be determined that about twice as much phosphorus leaves the farm in grain farming as in live-stock farming; and, in consequence, it is to be expected that the application of phosphorus will produce greater effects in the grain-farming system than in live-stock farming.

Table 4 contains more complete data for the corn crops grown on these fields, including the average yields of 1895-1897, before any treatment was applied. (For full details, see Bulletin 125.)

It should be noted that no manure was applied during the first rotation, 1902-1904; and that crop residues have been returned only during the last rotation, 1908-1910. (On plots 2, 4, 6, and 8 some legume catch crops have been seeded in the corn at the time of the last cultivation, but the results have not shown any benefit where oats follow corn, because with a good growth of corn the catch crop makes but little growth the same season, and there is no opportunity for it the following spring where the land must be seeded to oats.)

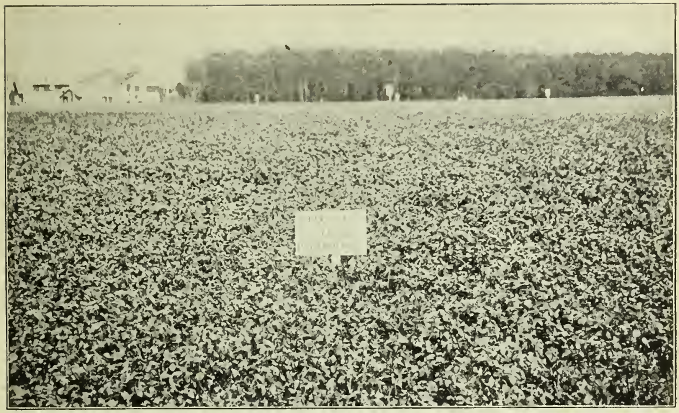


PLATE 4. CLOVER ON URBANA EXPERIMENT FIELD
LEGUME CROPS AND CROP RESIDUES PLOWED UNDER
LIMESTONE AND PHOSPHORUS APPLIED

TABLE 4.—AVERAGE CORN YIELDS PER ACRE ON URBANA EXPERIMENT FIELD, ON COMMON CORN BELT PRAIRIE SOIL: BROWN SILT LOAM

Plot No.	1	2	3	4	5	6	7	8	9
Corn, 1895-7........	61.2	63.4	61.2	63.1	66.1	65.9	65.7	64.0	65.9
Plan of treatment partially begun, 1902.....	None	Residues	Manure	Residues, lime	Manure, lime	Residues, lime, phosphorus	Manure, lime, phosphorus	Residues, lime, phosphorus, potassium	Manure, lime, phosphorus, potassium
Corn, 1902-4........	75.4	77.4	75.3	78.4	80.8	88.0	88.8	90.1	90.5
Corn, 1905-7.......	71.5	68.5	80.5	72.3	84.8	90.4	93.2	93.8	95.6
Corn, 1908-10....	49.4	51.5	69.3	58.1	74.9	83.8	86.6	86.7	90.9

Average Increase from Treatment Named: Corn, bushels

By additions	Residues	Manure	Lime	Lime	Phosphorus	Phosphorus	Potassium	Potassium
1902-4; 3 yrs	.....	....	1.0	5.5	9.6	8.0	2.1	1.7
1905-7; 3 yrs...........	......	9.0	3.8	4.3	18.1	8.4	3.4	2.4
1908-10; 3 yrs...........	2.1	19.9	6.6	5.6	25.7	11.7	2.9	4.3

Even though the grain system was not fully underway, the organic manures, limestone and phosphorus increased the yield of corn by 34.4 bushels per acre in grain farming, and by 37.2 bushels in live-stock farming, as an average of the last three years.

Wheat is grown on the University South Farm, in a rotation experiment started more recently. As an average of the last three years, 1908-1910, raw rock phosphate (with no previous applications of bone meal) has increased the yield of wheat by 8.4 bushels per acre, and here too the phosphorus has paid back more than twice its cost, as an average of the

PLATE 5. WHEAT IN 1911 ON URBANA FIELD
CATCH CROPS AND CROP RESIDUES PLOWED UNDER
AVERAGE YIELD, 35.2 BUSHELS PER ACRE

last three years, the cost being $1.87½, and the value of the increase $3.81 per acre per annum, wheat being valued at 70 cents a bushel and other crops as noted above. (Only five-sixths as much rock phosphate is applied on the South Farm as is reported above for the third rotation in the North Farm experiments, and even this application will be reduced one-half or more after the soil has become sufficiently rich for the production of maximum crops.)

Since the above was written the 1911 crop of wheat has been harvested and threshed on the University South Farm.

In the grain system of farming, the yield was 35.2 bushels per acre where catch crops and crop residues have been plowed under without the use of phosphorus; but where rock phosphate has been used the average yield was 50.1 bushels in the same system. (See Plates 5 and 6.)

In the live-stock farming, the yield was 34.2 bushels where manure and catch crops are used without phosphate, and 51.8 bushels, as an average, where rock phosphate is used in connection with the live-stock system. (See Plates 7 and 8.)

PLATE 6. WHEAT IN 1911 ON URBANA FIELD
CATCH CROPS AND CROP RESIDUES PLOWED UNDER
FINE-GROUND ROCK PHOSPHATE APPLIED
AVERAGE YIELD, 50.1 BUSHELS PER ACRE

These results emphasize the cumulative effect of permanent systems of soil improvement. The value of the increase produced by phosphorus in the 1911 wheat crop alone would nearly pay for the cost of the phosphate for eight years.

RESULTS OF EXPERIMENTS ON SIBLEY FIELD

Table 5 gives results obtained during the past nine years from the Sibley soil experiment field, located in Ford County on typical brown silt loam prairie of the Illinois corn belt.

Previous to 1902 this land had been cropped with corn and oats for many years under a system of tenant farming and the soil had become somewhat deficient in active humus. While phosphorus was the limiting element of plant food, the supply of nitrogen becoming available annually was but little in excess of the phosphorus, as is well shown by the corn yields for 1903, when phosphorus produced an increase of 8 bushels, nitro-

PLATE 7. WHEAT IN 1911 ON URBANA FIELD
CATCH CROPS AND FARM MANURE PLOWED UNDER
AVERAGE YIELD, 34.2 BUSHELS PER ACRE

gen without phosphorus produced no increase, but nitrogen and phosphorus increased the yield by 15 bushels.

After six years of additional cropping, however, nitrogen appears to have become the most limiting element, the increase in 1907 being 9 bushels from nitrogen and only 5 bushels from phosphorus, while both together produced an increase of 33 bushels of corn. By comparing the corn yields for the four years, 1902, 1903, 1906 and 1907, it will be seen that the untreated land has apparently grown less productive, whereas on land receiving both phosphorus and nitrogen the yield has appreciably increased, so that in 1907, when the untreated rotated land produced only 34 bushels of corn per acre, a yield of 72 bushels, or more than twice as much, was produced where lime nitrogen and phosphorus had been applied, altho these two plots produced exactly the same yield (57 bushels) in 1902.

Even in the unfavorable season of 1910 the highest yielding plot exceeded that of 1902, while the untreated land produced less than half as much. Phosphorus appears to have been the first limiting element again in 1909 and 1910.

PLATE 8. WHEAT IN 1911 ON URBANA FIELD
CATCH CROPS AND FARM MANURE PLOWED UNDER
FINE-GROUND ROCK PHOSPHATE APPLIED
AVERAGE YIELD, 51.8 BUSHELS PER ACRE

In the lower part of Table 5 are shown the total values per acre of the nine crops from each of the ten different plots, the amounts varying from \$140.17 to \$214.96; also the value of the increase produced; first, above the untreated land; and, second, above the treatment with lime alone, corn being valued at 35 cents a bushel, oats at 30 cents and wheat at 70 cents.

Phosphorus without nitrogen produced \$24.44 in addition to the increase by lime; and with nitrogen phosphorus produced \$56.14 in addition to the increase by lime and nitrogen, the principal part of these increases having been made during the later years.

The results show that in 21 cases out of 36 the addition of potassium decreased the crop yields.

By comparing plots 101 and 102, and also 109 and 110, it will be seen that the average increase by lime was \$9.90, or more than \$1.00 an acre a year, suggesting that the time is near when limestone must be applied to these brown silt loam soils.

TABLE 5—CROP YIELDS IN SOIL EXPERIMENTS: SIBLEY FIELD

Brown silt loam prairie; Early Wisconsin glaciation		Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910
Plot	Soil treatment applied	Bushels per acre								
101	None	57.3	50.4	74.4	29.5	36.7	33.9	25.9	25.3	26.6
102	Lime	60.0	54.0	74.7	31.7	39.2	38.9	24.7	28.8	34.0
103	Lime, nitrogen	60.0	54.3	77.5	32.8	41.7	48 1	36.3	19.0	29.0
104	Lime, phosphorus	61.3	62.3	92.5	36.3	44.8	43.5	25.6	32.2	52.0
105	Lime, potassium	56.0	49.9	74.4	30.2	37.5	34.9	22.2	23.2	34.2
106	Lime, nitrogen phosphorus	57.3	69.1	88.4	45.2	68.5	72.3	45.6	33.3	55.6
107	Lime, nitrogen potassium	53.3	51.4	75.9	37.7	39.7	51.1	42.2	25.8	46.2
108	Lime, phosphorus potassium	58.7	60.9	80.0	39.8	41.5	39.8	27.2	28.5	43.0
109	Lime, nitrogen, phosphorus, potassium	58.7	65.9	82.5	48.0	69.5	80.1	52.8	35.0	58.0
110	Nitrogen, phosphorus, potassium	60.0	60.1	85.0	48.5	63.3	72.3	44.1	30.8	64.4

VALUE OF CROPS PER ACRE IN NINE YEARS

Plot	Soil treatment applied	Total value of nine crops	Value of increase	
				Over lime
101	None	$140.17	....	
102	Lime	151.30	$11.13	
103	Lime, nitrogen	151.99	11.82	$ .69
104	Lime, phosphorus	175.74	35.57	24.44
105	Lime, potassium	140.73	.56	(-10.57)
106	Lime, nitrogen, phosphorus	208.13	67.96	56.83
107	Lime, nitrogen, potassium	164.48	24.31	13.18
108	Lime, phosphorus, potassium	165.33	25.16	14.03
109	Lime, nitrogen, phosphorus, potassium	214.96	74.79	63.66
110	Nitrogen, phosphorus, potassium	206.28	66.11	....

RESULTS OF EXPERIMENTS ON BLOOMINGTON FIELD

Space is taken to insert Table 6, giving all of the results thus far obtained from the Bloomington soil experiment field, which is also located on the brown silt loam prairie soil of the Illinois corn belt.

The general results of the nine years' work on the Bloomington field tell the same story as those from the Sibley field. The rotations differed by the use of clover and by discontinuing the use of commercial nitrogen, after 1905, on the Bloomington field, in consequence of which phosphorus without commercial nitrogen (Plot 104) produced practically the same increase ($56.05) as was produced by phosphorus over nitrogen on the Sibley field (see Plots 103 and 106).

TABLE 6.—CROP YIELDS IN SOIL EXPERIMENTS: BLOOMINGTON FIELD

Plot	Brown silt loam prairie; Early Wisconsin glaciation	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Corn 1908	Oats 1909	Clover 1910†
	Soil treatment applied	Bushels or tons per acre								
101	None	30.8	63.9	54.8	30.8	.39	60.8	40.3	46.4	1.56
102	Lime	37.0	60.3	60.8	28.8	.58	63.1	35.3	53.6	1.09
103	Lime, nitrogen	35.1	59.5	69.8	30.5	.46	64.3	36.9	49.4	(.83)
104	Lime, phosphorus	41.7	73.0	72.7	39.2	1.65	82.1	47.5	63.8	4.21
105	Lime, potassium	37.7	56.4	62.5	33.2	.51	64.1	36.2	45.3	1.26
106	Lime, nitrogen, phosphorus	43.9	77.6	85.3	50.9	*	78.9	45.8	72.5	(1.67)
107	Lime, nitrogen, potassium.	40.4	58.9	66 4	29.5	.81	64.3	31.0	51.1	(.33)
108	Lime, phosphorus, potassium	50.1	74.8	70.3	37.8	2.36	81.4	57.2	59.5	3.27
109	Lime, nitrogen, phosphorus potassium	52.7	80.9	90.5	51.9	*	88.4	58.1	64.2	(.42)
110	Nitrogen, phosphorus potassium	52.3	73.1	71.4	51.1	*	78.0	51.4	55.3	(.60)

VALUE OF CROPS PER ACRE IN NINE YEARS

Plot	Soil treatment applied	Total value of nine crops	Value of increase	
101	None	$132 15	....	Over lime
102	Lime	133.00	$ .85	
103	Lime, nitrogen (see text)	133.38	1.23	$ .38
104	Lime, phosphorus	189.05	56.90	56.05
105	Lime, potassium	134.24	2.09	1.24
106	Lime, nitrogen, phosphorus	179.16	47.01	46.16
107	Lime, nitrogen, potassium.	130.85	(-1.30)	(-2.15)
108	Lime, phosphorus, potassium	191.40	59.25	58.40
109	Lime, nitrogen, phosphorus, potassium	183.29	51.14	50.29
110	Nitrogen, phosphorus, potassium	166.56	34.41	....

*Clover smothered out by previous very heavy wheat crop. After the clover hay was harvested all ten of the plots were seeded to cowpeas and the crop was plowed under later on all plots as green manure for the 1907 corn crop.

†The figures in parentheses represent bushels of clover seed: the others, tons of clover hay (in two cuttings) in 1910.

It should be stated that a draw runs near plot 110 on the Bloomington field and the crops on that plot are sometimes damaged by overflow or imperfect drainage; also that in 1902 the stand of corn on the Bloomington field was poor, though fairly uniform. Otherwise all results reported in Tables 5 and 6, including more than 150 tests, are considered reliable, and they furnish much information and instructive comparisons.

Wherever nitrogen was provided either by direct application or by the use of legume crops the addition of the element phosphorus produced very marked increases, the average value being $56.10 for the nine years, or $6.23 an acre a year. This is $3.73 above its cost in 200 pounds of steamed bone meal, the form in which it was applied to these fields. On the other

hand, the use of phosphorus without nitrogen will not maintain the fertility of the soil (see Plots 104 and 106, Sibley field); and a liberal use of clover or other legumes is suggested as the only practical and profitable method of supplying the nitrogen, the clover to be plowed under, either directly or as manure, preferably in connection with the phosphorus applied, especially if raw rock phosphate is used.

From the best treated plots 130 pounds per acre of phosphorus have been removed from the soil in the nine crops. This is equal to 11 percent of the total phosphorus contained in the surface soil of an acre of the untreated land. In other words, if such crops could be grown for 80 years they would require as much phosphorus as the total supply in the ordinary plowed soil. The results plainly show, however, that without the addition of phosphorus such crops cannot be grown year after year. The total phosphorus applied from 1902 to 1910 amounted to 225 pounds per acre. Where no phosphorus was applied the crops removed only 90 pounds of phosphorus in nine years, equivalent to only 7½ percent of the total amount (1,200 pounds) in the surface soil at the beginning (1902).

THE SUBSURFACE AND SUBSOIL

In Tables 7 and 8 are recorded the amounts of plant food in the subsurface and subsoils, but it should be remembered that these supplies are of little value unless the top soil is kept rich. Probably the most important information contained in Tables 7 and 8 is that the upland timber soils are more strongly acid in the subsurface and subsoil than in the surface, thus emphasizing the importance of having plenty of limestone in the surface soil to neutralize the acid moisture which rises from the lower strata by

TABLE 7.—FERTILITY IN THE SOILS OF MOULTRIE COUNTY, ILLINOIS

Average pounds per acre in 4 million pounds of subsurface soil (about 6⅔ to 20 inches)

Soil Type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone requir'd
				Upland Prairie Soils					
1126	Brown silt loam	67420	6480	1590	72590	20160	18170	140	
1120	Black clay loam (normal phase).	71140	6220	2650	72340	30020	36350	23760	
1120	Black clay loam (lighter phase).	30040	4000	2000	65720	38720	38480	82780	
				Upland Timber Soils					
1132	Light gray silt loam on tight clay..........	16740	1840	920	70740	19120	11240		4520
1134	Yellow-gray silt loam	17650	2040	1100	74680	18530	10230		1840
1135	Yellow silt loam	17160	1720	1200	80520	25280	8440		6760
				Swamp and Bottom-Land Soils					
1454	Mixed loam (normal phase).	71240	6240	2000	80920	21640	28720	2200	
1454	Mixed loam (lighter phase).	48680	5680	1320	81840	20680	25920	1000	
				Terrace Soil					
1554.6	Mixed loam over sand or gravel	8960	1360	1040	73720	15440	11720		160

capillary action during periods of partial drouth, which are also critical periods in the life of such plants as clover. Thus, while the common brown silt loam prairie soil is practically neutral, the upland soils that are or were timbered are already in need of limestone as a rule; and, as already explained, they are much more deficient in phosphorus and nitrogen than the common prairie.

TABLE 8.—FERTILITY IN THE SOILS OF MOULTRIE COUNTY, ILLINOIS

Average pounds per acre in 6 million pounds of subsoil (about 20 to 40 inches)

Soil Type No.	Soil type	Total organic carbon	Total Nitrogen	Total Phosphorus	Total Potassium	Total Magnesium	Total Calcium	Limestone present	Limestone requir'd
	Upland Prairie Soils								
1126	Brown silt loam	29180	3720	2230	109670	46360	30790	7860	
1120	Black clay loam (normal phase).	39230	3670	3130	112730	50690	72840	126200	
1120	Black clay loam (lighter phase).	19800	2340	2280	83760	121020	510720	1638120	
	Upland Timber Soils								
1132	Light gray silt loam on tight clay..........	23280	2670	2070	112380	46770	30990		90
1134	Yellow-gray silt loam.......	18510	2360	1830	126570	41510	18380		5480
1135	Yellow silt loam	14820	2100	2040	143400	46200	16140		480
	Swamp and Bottom-Land Soils								
1454	Mixed loam (normal phase).	41760	4500	2160	127020	34260	35580	1020	
1454	Mixed loam (lighter phase).	39360	4500	1920	118200	28320	32580	5340	
	Terrace Soil								
1554.6	Mixed loam over sand or gravel........	7980	1380	1320	101460	26340	16740		2580

INDIVIDUAL SOIL TYPES

(a) UPLAND PRAIRIE SOILS

Brown Silt Loam (1126)

This type occupies 77.5 percent of the area of the county or 264.42 square miles, equal to 169,229 acres. It has been formed from wind-blown loessial material mixed with organic matter furnished by the roots of prairie grasses that formerly grew on the native prairies. The topography varies from nearly flat to rolling, the larger part of the type being sufficiently sloping to insure good surface drainage, while the rest is in good condition for tile drainage.

The surface soil, 0 to 6⅔ inches, is a brown silt loam, but near the boundaries it varies on the one hand to almost black as it passes toward black clay loam, and on the other to a grayish brown or yellowish brown as it grades into the timber types. It contains enough of the coarser constituents, sand and coarse silt, to make it work easily, and yet enough clay to give stability to the soil. The organic matter content varies from 3½ to 5 percent, the amount depending upon topography to a considerable extent. The lower and more poorly drained areas permitted the accumulation of a larger amount than the higher land because of ranker growth of grasses as well as less decay on account of moisture.

The thickness of the subsurface varies from 7 to 14 inches, and in color from a dark brown to a light yellowish brown silt loam, the color and depth varying with the topography, being lighter in color and shallower on the more rolling areas.

The subsoil to a depth of 40 inches is a yellow clayey silt or silty clay, somewhat plastic when wet. The color is of a brighter yellow, even somewhat reddish, where there has been good surface drainage, and of a pale yellow, approaching an olive color, where poorly drained. In some of the rolling areas the loess deposit has been partly removed by washing, thus bringing the glacial drift within 40 inches of the surface. This is of rare occurrence in Moultrie County.

In the management of this soil, one necessary thing, aside from proper drainage and good tillage, is to keep it in good physical condition or in good tilth. It is a common practice in the corn belt to pasture the corn stalks during the winter and often late in the spring, so late in fact that tramping puts the soil in bad condition for working. It is partially puddled and will be cloddy as a result. If thus tramped in the spring, the natural agencies of freezing and thawing, wetting and drying, even with the aid of ordinary tillage, fail to produce good tilth before the crop is planted and the latter necessarily suffers. This will be much worse if the season should be dry. A poor stand of corn will result, if the field is put in corn, and a compact baked soil unfavorable for growth, if put in oats. Sometimes farmers will not wait for their soils to become sufficiently dry to work well, and a puddled soil results which is very unfavorable to physical, chemical, and biological processes. This will be especially true if cropping has reduced the amount of organic matter below what is necessary to maintain good tilth. Every practicable means should be used to maintain the supply of this constituent. Clover should be grown every three or four years and the bulk of the crop turned under, either directly or after removing the seed

or after feeding and bringing back all the manure. All straw should be returned to the land and plowed under if not used as bedding or fed, and stalks should be chopped up and turned under as well as weeds and trash. In this way only can the present fair supply of organic matter and its accompanying nitrogen be maintained in this soil. The supply of phosphorus as shown by field experiment is inadequate for the highest economical production, and this should be increased by turning under with the clover sod every three or four years at least one-half ton of rock phosphate per acre, and the initial application may well be a ton or more per acre.

On the lighter phase of the type and upon higher points of the better phase, the immediate use of ground limestone per acre (about two tons every four or five years) is to be recommended. In the near future, for the continued successful growing of clover, alfalfa, and other legumes, limestone will generally have to be used upon this type of soil.

Black Clay Loam (1120)

This type of soil, commonly found in the originally swampy or poorly drained areas of the Early Wisconsin Glaciation, is frequently called "gumbo," because of its sticky character. Its formation in these low places is due to the accumulation of organic matter and the washing in of the clay and other fine material from the slightly higher uplands. On account of the good surface drainage that exists generally in this county, the black clay loam constitutes only 4.5 percent of the entire area, or 9,858 acres.

The topography of this type is flat, yet for all areas of black clay loam sufficient "outlets" for tile may be secured so that good drainage is possible

The surface stratum, 0 to 6⅔ inches, is a black, plastic clay loam containing from 5 to 7 percent of organic matter, or from 50 to 70 tons in an acre. The surface soil is naturally quite granular and consequently pervious to water. This granular character is a very desirable property for all soils, but especially for heavy ones. It keeps the soil mellow and if the granules are destroyed by working while wet or by the tramping of stock, they will be formed again by freezing and thawing and by moisture changes (wetting and drying). These produce slacking, as the process is usually termed. If, however, the humus and lime content become low, this tendency to granulate grows less and the soil becomes more difficult to work.

The subsurface stratum, from 10 to 16 inches thick, is about the same as the surface, except that it becomes lighter with depth so that the lower part of this stratum may pass into a drab or yellowish silty clay. It is pervious to water, due to the jointing or checking produced by shrinkage in times of drouth.

The subsoil below 20 inches is usually a drab or dull yellow silty clay but locally may be a yellow clayey silt. As a rule the subsoil is not so highly colored as that of the better drained types, due to the fact that the iron is not so highly oxidized in this poorly drained subsoil. The subsoil is checked and jointed somewhat the same as the subsurface.

This type presents many variations. It must be borne in mind that the boundary lines between different soil types are not always distinct but that types frequently pass from one to the other very gradually, thus giving a zone of greater or less width intermediate between the two types. The black clay loam (1120) is usually surrounded by brown silt loam (1126)

and it would be expected that the two would grade into each other. This gives variations including a lighter phase containing less of clay and organic matter than the average of the type. In some areas there has been enough silty material washed in from the surrounding higher land to modify the character of the surface soil. This is true of the Eagle Pond district in Sections 14, 23, 24 and 26, in Township 14 North, Range 5 East of the Third P.M., and particularly in small areas surrounded by higher land. This change is taking place more rapidly now with annual cultivation of soil than formerly when prairie grass protected the land from washing.

The amount of coarse soil constituents, sand and gravel, varies in this type. These have been brought up to some extent from the underlying glacial drift by burrowing animals, especially crayfish, and distributed thru the soil.

Drainage is the first requirement of this type, and altho but very slightly sloping, yet this with the perviousness of the soil gives an excellent chance for surface and tile drainage. Keeping the soil in good physical condition is very essential, and thoro drainage helps to do this to a great extent. As the organic matter is destroyed and the lime removed from the soil, the former by cultivation and decomposition and the latter by cropping and leaching, the soil will attain a poorer physical condition and consequently become more difficult to work. Both the organic matter and the lime tend to develop granulation of the soil. The former should be maintained by turning under manure or clover and residues from crops, such as cornstalks, stubble and straw, and ground limestone should be applied where needed.

While this soil is one of the best in the state, yet the clay and humus which it contains give it the property of shrinkage and expansion to such a degree as to be somewhat objectionable at times. When the soil is wet, these constituents expand, and when the moisture evaporates or is used by plants, the soil shrinks. This results in the formation of cracks up to two inches or more in width and extending with lessening width to a depth of a foot or more. These cracks allow the subsoil to dry out rapidly. They sometimes "block out" the hills of corn by cross cracks, severing the roots and thus confining each hill to a comparatively small area. Sometimes much damage to the crop results. While cracking may not be prevented entirely in this type, yet it may be controlled to some extent by a soil mulch to check evaporation and prevent the cracks from extending to the surface. Organic matter, as cornstalks or straw, applied to the surface in liberal amount, also makes a very satisfactory mulch, but of course this would interfere with ordinary cultivation and cropping.

This type of soil is well supplied with organic matter and nitrogen. It has about eighty percent more phosphorus than does the brown silt loam and is abundantly supplied with potassium. As a rule, it contains limestone in sufficient amounts for present use. Upon this soil it is of first importance to establish a system which will maintain the supply of actively decaying organic matter and to so handle it as to keep the soil in good tilth. Eventually the use of limestone and phosphorus may be profitable; and on the lighter phase, indicated by the lighter color and greater friability (because of its higher content of silt), applications of phosphorus can even now be made profitable in good systems of farming.

(b) UPLAND TIMBER SOILS

Light Gray Silt Loam on Tight Clay (1132)

This type comprises only 1.4 percent of the area of the county or 3,040 acres. It is found almost entirely in the southern part of the county in the timbered areas along the Kaskaskia river and its tributaries. As a rule, it occurs in small, level, but not swampy areas that have poor drainage on account of the topography and the imperviousness of the subsoil. Practically all of this type is now cleared and under cultivation, but the trees formerly growing upon it were white oak, shellbark hickory, black jack and some post oak.

The surface soil, 0 to 6⅔ inches, is a light gray silt loam, incoherent, friable, and porous. Iron concretions, varying in size from ¼ inch to a pin head are usually present in this stratum. The organic matter content is very low, being about 1½ per cent.

The subsurface is a light gray silt becoming slightly yellowish and more clayey with depth.

The subsoil below 20 inches is a compact clayey silt, yellow in color with gray or drab mottlings. The subsoil below 35 or 40 inches is usually coarser and more pervious to water.

The soil runs together after a rain, and limestone with organic matter will prevent this to a very great extent.

Some carefully conducted experiments are needed to ascertain the feasibility of tile-drainage in this land.

In the management of this type the most practical things to do are to apply limestone and phosphorus and increase the content of organic matter in every way practicable. The subsoil is tight and the growing of deep-rooting crops such as red, mammoth, or sweet clover would tend to make it more porous as well as supply the soil with organic matter and nitrogen.

Yellow-Gray Silt Loam (1134)

This type occurs in the timbered area along the Kaskaskia river and its tributaries, principally in the southern part of the county, forming strips along the streams with a broadening toward the north and east sides of the streams where the timber was protected from the prairie fires driven by the prevailing south-westerly winds.

The type occupies about 10.3 percent of the total area of the county or 22,412 acres, being next in amount to the brown silt loam. This type is sufficiently rolling for good drainage without much tendency to wash, if anything like proper care is taken of the soil.

The surface soil, 0 to 6⅔ inches, is a gray to yellowish gray silt loam, incoherent and mealy but not granular. It is low in organic matter content, averaging about 2¼ per cent.

The characteristic stratum in the subsurface varies from 3 to 10 inches in thickness and consists of a gray, grayish yellow, or yellow silt loam, somewhat mealy but becoming more coherent and clayey with depth. Only a small amount of organic matter is present.

The subsoil is a yellow or grayish mottled yellow clayey silt or silty clay, somewhat plastic when wet, but friable when only moist. Where erosion has occurred, glacial drift sometimes forms all or part of the subsoil.

This type is quite variable, due to the fact that it grades into so many different types. It is very probable that all or very nearly all of the timbered area was at one time a part of the prairie and the present character of the soil has been produced by the gradual invasion and long occupancy of forest growth. Certain trees, such as elm, hard maple, wild cherry, hackberry, and black walnut, were the first to spread over the prairie. Long periods (perhaps thousands of years) were required to produce much change in soil. Other trees followed the above, and the growth of grasses to which the accumulation of organic matter is largely due was gradually diminished by shading and growth of underbrush, after which little or no organic matter was added and incorporated with the soil. The leaves of the trees falling upon the surface were either burned or decayed completely without being mixed with the soil and gradually the organic matter content was reduced until a gray silt loam or a yellow-gray silt loam was the result. There is frequently a zone of land (too narrow to map) that represents a transition between the brown silt loam and the timber type in which the surface soil is brown or grayish brown and the subsurface is grayish brown to gray. This gives a phase of the type that is better than the average, especially as to its content of organic matter.

The topography is generally undulating to rolling, becoming in some places sufficiently rolling so that considerable washing may occur if not properly managed.

To prevent this washing, as well as to supply a deficient and much needed constituent, every practicable means should be employed to increase the organic matter content of this type. "Running together" is a fault of this soil that may thus be largely prevented.

The absence of limestone in the subsoil indicates the advisability of using limestone upon this soil in order to grow clover, alfalfa, and other legumes more successfully. The soil is also very deficient in phosphorus, which must be liberally supplied in any practicable system for the marked and profitable improvement of this soil.

Yellow Silt Loam (1135)

This type covers only 1,402 acres, or less than one percent of the total area of the county. It occurs as narrow irregular strips adjoining the bottom-lands of the Kaskaskia river, or as arms projecting into other types and marking the location of small streams that have eroded to considerable depth.

The topography is very rolling to broken, so steep in many places that it cannot be cultivated and much of it should not be, because of the danger of injury from washing.

The surface soil, 0 to 6⅔ inches, is a grayish yellow, pulverulent, mealy silt loam, somewhat porous. Where much recent washing has taken place, the surface soil does not differ materially from the subsoil.

The typical subsurface varies considerably, depending upon the amount of washing that has taken place. In thickness it varies from 0 to 12 inches, the variation being due to the removal of the surface. In fact, in many places both surface and subsurface have been removed exposing the subsoil.

This latter consists of a compact yellow clayey silt but in places the glacial drift may form the whole or part of the subsoil, or occasionally it may even form the surface soil in small patches.

In the management of this type the chief thing is to prevent general surface washing and gullying. If it is cropped at all, a rotation should be practiced that will require a cultivated crop as little as possible and allow as much pasture or meadow as possible. If tilled, the land should be plowed deeply and contours should be followed as nearly as possible. Furrows extending up and down the slopes should be avoided. Planting and cultivation should be done in the same direction as plowing. Every means should be employed to maintain and increase the organic matter content to help hold the soil and keep it in good physical condition so it will absorb a large amount of water and thus diminish the run off. (See Circular 119.)

Limestone can be used with profit on this type of soil where it is to be cropped or prepared for seeding down. Even top-dressings of limestone will usually help to increase the leguminous plants in the herbage of permanent pastures.

The application of phosphorus is not advised, unless special precautions are taken to prevent surface erosion; and, if used at all, the phosphorus should be mixed with the surface soil by disking and then plowed under, so as to put the phosphorus down where the plant roots feed, and thus reduce the danger of loss of applied phosphorus by erosion.

(c) Swamp and Bottom-land Soils

Bottom-lands are usually named from their distances above the streams as first, second, third, etc. The first bottom represents the flood plain of the stream. The highest bottom is the oldest and shows the height to which the old valley was once filled.

Mixed Loam (1454)

The first bottom or overflow land along the streams in the county is called mixed loam. These small bottom lands vary a great deal in the kind of soil, and the areas of these different types are so small that it would be entirely impracticable to separate them. Moreover, the soils are changed by floods so that a separation of types would not mean very much after a few years. The total area is only 8,781 acres, or a little more than four percent of the area of the county.

The topography is generally flat, but occasionally an area is found that has undulating surface due to the overflow stream channels that give a little diversity to the topography.

The surface soil, 0 to 6⅔ inches, varies from a dark brown silt loam, or even clay loam, to a brown loam and light brown sandy loam. The lower and more nearly level areas are heaviest and blackest while the undulating areas are more loamy and sandy.

The subsurface soil is very similar to but lighter in color than the surface. There is sometimes no distinct line separating the subsurface from the subsoil, the only difference frequently being a lighter color. In the sandy areas the subsoil is generally more sandy, sometimes becoming a sand.

While the normal phase is only moderately rich and the lighter phase is rather low in nitrogen and phosphorus, the soil is usually very deep and thus affords a very extensive feeding range for plant roots. Drainage and protection from overflow are the considerations of first importance in dealing with this soil.

(d) TERRACE SOILS

Mixed Loam over Sand or Gravel (1554.6)

This type which forms only 1.6 percent of the area of the county, or 3,516 acres, occurs along the Kaskaskia proper and the West Fork of that stream. The areas are somewhat isolated and represent an old fill or bottom-land probably formed by the melting of the Wisconsin Glacier at a time when the river was overloaded with ground-up material from the melting glacier. The streams have later cut down thru this deposit and developed a new bottom that is from 10 to 30 feet below the terrace. Much of the material that filled this old valley was gravel and coarse sand which now form the underlying stratum of this type. The topography varies from almost level to a gentle slope and in some areas gently undulating.

The surface soil, 0 to 6 ⅔ inches, varies from a brown or yellow silt loam to a loam or sandy loam. The variations are in too small areas to permit their being shown separately on the map. As a general rule, there is more sand in the soil near the first bottom than farther back. This is probably due to the sand being blown up from the lower bottom-land.

The subsurface stratum is from 6 to 12 inches in thickness, being a light brown to yellow silt loam with variations of sand content similar to that of the surface soil.

The subsoil is a yellow silt varying to a sandy silt or sandy loam sufficiently open and pervious to allow good drainage. Underlying the subsoil at a depth of from three to six feet is a bed of gravel or sand that provides good underdrainage. In dry seasons where the gravel is nearest the surface, the crop may suffer from drouth because of the inability of the gravel to draw the moisture up from below on account of its coarseness and consequent low capillary power.

This soil is one of the poorest in the area in phosphorus, nitrogen, and organic matter, thus resembling the yellow silt loam, from which it receives some surface wash in places; but its topography is such as to justify the adoption of definite plans for improving this soil to a high state of productiveness. Large use of organic manures and liberal applications of phosphorus are the chief essentials, the addition of phosphorus being less important on the more sandy areas, because of the deep feeding range there afforded for plant roots.

In places the soil is acid and as an average the subsurface and subsoil are acid. In soils of such variable character the landowner should thoroly test the soil and subsoil for acidity, using a few cents' worth of blue litmus paper and following the directions given in Circular 110, "Ground Limestone for Acid Soils," which also contains directions for making a machine for spreading phosphate and limestone, and will be sent to any one free of charge upon application to the Agricultural Experiment Station.

APPENDIX

A study of the soil map and the tabular statements concerning crop requirements, the plant food content of the different soil types, and the actual results secured from definite field trials with different methods or systems of soil improvement, and a careful study of the discussion of general principles and of the descriptions of individual soil types will furnish the most necessary and useful information for the practical improvement and permanent preservation of the productive power of every kind of soil on every farm in the county.

More complete information concerning the most extensive and important soil types in the great soil areas in all parts of Illinois is contained in Bulletin No. 123, "The Fertility in Illinois Soils," which contains a colored general survey soil map of the entire state.

Other publications of general interest are:

Bulletin No. 76, "Alfalfa on Illinois Soils."

Bulletin No. 94, "Nitrogen Bacteria and Legumes."

Bulletin No. 99, "Soil Treatment for the Lower Illinois Glaciation."

Bulletin No. 115, "Soil Improvement for the Worn Hill Lands of Illinois."

Bulletin No. 125, "Thirty Years of Crop Rotation on the Common Prairie Lands of Illinois."

Circular No. 110, "Ground Limestone for Acid Soils."

Circular No. 127, "Shall we use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils?"

Circular No. 129, "The Use of Commercial Fertilizers."

Circular No. 149, "Some Results of Scientific Soil Treatment" and "Methods and Results of Ten Years' Soil Investigation in Illinois."

NOTE.—Information as to where to obtain limestone, phosphate, bone meal, and potassium salts, methods of application, etc., will also be found in Circulars 110 and 149.

SOIL SURVEY METHODS

The detail soil survey of a county consists essentially of indicating on a map the location and extent of the different soil types; and, since the value of the survey depends upon its accuracy, every reasonable means is employed to make it trustworthy. To accomplish this object three things are essential: first, careful, well-trained men to do the work; second, an accurate base map upon which to show the results of their work; and, third, the means necessary to enable the men to place the soil-type boundaries, streams, etc., accurately upon the map.

The men selected for the work must be able to keep their location exactly and to recognize the different soil types, with their principal varieties and limits, and they must show these upon the maps correctly. A definite system is employed in checking up this work. As an illustration, one soil expert will survey and map a strip 80 rods or 160 rods wide and any convenient length, while his associate will work independently on another strip adjoining this area, and, if the work is correctly done, the soil type boundaries will match up on the line between the two strips.

An accurate base map for field use is absolutely necessary for soil mapping. The base maps are made on a scale of one inch to the mile. The official data of the original or subsequent land survey are used as a basis in the construction of these maps, while the most trustworthy county map available is used in locating temporarily the streams, roads, and railroads. Since the best of these published maps have some inaccuracies, the location of every road, stream, and railroad must be verified by the soil surveyors, and corrected if wrongly located. In order to make these verifications and corrections, each survey party is provided with an odometer for measuring distances, and a plane table for determining the directions of roads, railroads, etc.

Each surveyor is provided with a base map of the proper scale, which is carried with him in the field; and the soil-type boundaries, additional streams, and necessary corrections are placed with proper locations upon the map while the mapper is on the area. Each section, or square mile, is divided into 40-acre plots on the map and the surveyor must inspect every ten acres and determine the type or types of soil composing it. The different types are indicated on the map by different colors, pencils being carried in the field for this purpose.

A small auger 40 inches long forms for each man an invaluable tool with which he can quickly secure samples of the different strata for inspection. An extension for making the auger 80 inches long is taken by each party, so that any peculiarity of the deeper subsoil layers may be studied. Each man carries a compass to aid in keeping directions. Distances along roads are measured by an odometer attached to the axle of the vehicle, while distances in the field off the roads are determined by pacing, an art in which the men become expert by practice. The soil boundaries can thus be located with as high a degree of accuracy as can be indicated by pencil on the scale of one inch to the mile.

SOIL CHARACTERISTICS

The unit in the soil survey is the soil type, and each type possesses more or less definite characteristics. The line of separation between adjoining types is usually distinct, but sometimes one type will grade into another so gradually that it is very difficult to draw the line between them. In such exceptional cases, some slight variation in the location of soil-type boundaries is unavoidable.

Several factors must be taken into account in establishing soil types. These are (1) the geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial, or cumulose; (2) the topography, or lay of the land; (3) native vegetation, as forest or prairie grasses; (4) the structure, or the depth and character of the surface, subsurface, and subsoil; (5) the physical or mechanical composition of the different strata composing the soil, as the percentages of gravel, sand, silt, clay, and organic matter which they contain; (6) the texture, or porosity, granulation, friability, plasticity, etc.; (7) the color of the strata; (8) the natural drainage; (9) agricultural value, based upon its natural productiveness; (10) the ultimate chemical composition and reaction.

The common soil constituents are indicated in the following outline:

CONSTITUENTS OF SOILS

Soil Constituents	Organic Matter	Comprising undecomposed and partially decayed vegetable material		
	Inorganic Matter	Clay	.001	mm.* and less
		Silt	.001	mm. to .03 mm.
		Sand	.03	mm. to 1. mm.
		Gravel	1.	mm. to 32 mm.
		Stones	32.	mm. and over.

*25 millimeters equal 1 inch.
Further discussion of these constituents is given in Circular 82.

GROUPS OF SOIL TYPES

The following gives the different general groups of soils:

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or silt.

Peaty loams—15 to 35 percent of organic matter mixed with much sand and silt and a little clay.

Mucks—15 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 25 percent of clay, usually mixed with much silt.

Clay loams—Soils with from 15 to 25 percent of clay, usually mixed with much silt and some sand.

Silt loams—Soils with more than 50 percent of silt and less than 15 percent of clay, mixed with some sand.

Loams—Soils with from 30 to 50 percent of sand mixed with much silt and a little clay.

Sandy loams—Soils with from 50 to 75 percent of sand.

Fine sandy loams—Soils with from 50 to 75 percent of fine sand mixed with much silt and little clay.

Sands—Soils with more than 75 percent of sand.

Gravelly loams—Soils with 25 to 50 percent gravel with much sand and some silt.

Gravels—Soils with more than 50 percent of gravel.

Stony loams—Soils containing a considerable number of stones over one inch in diameter.

Rock outcrop—Usually ledges of rock having no agricultural value.

More or less organic matter is found in nearly all of the above classes.

SUPPLY AND LIBERATION OF PLANT FOOD

The productive capacity of land in humid sections depends almost wholly upon the power of the soil to feed the crop; and this, in turn, depends both upon the stock of plant food contained in the soil and upon the rate at which this is liberated, or rendered soluble and available for use in plant growth. Protection from weeds, insects, and fungous diseases, tho exceedingly important, is not a positive but a negative factor in crop production.

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but the rate of liberation is governed by many factors, some of which may be controlled by the farmer, while others are largely beyond his control. Chief among the important controllable factors which influence the liberation of plant food are limestone and decaying organic matter, which may be added to the soil by direct application of ground limestone and farm manure. Organic matter may also be supplied by green-manure crops and crop residues, such as clover, cowpeas, straw, and cornstalks. The rate of decay of organic matter depends largely upon its age and origin, and it may be hastened by tillage. The chemical analysis shows correctly the total organic carbon, which represents, as a rule, but little more than half the organic matter; so that 20,000 pounds of organic carbon in the plowed soil of an acre corresponds to nearly 20 tons of organic matter. But this organic matter consists largely of the old organic residues that have accumulated during the past centuries because they were resistant to decay, and 2 tons of clover or cowpeas plowed under may have greater power to liberate plant food than the 20 tons of old inactive organic matter. The recent history of the individual farm or field must be depended upon for information concerning recent additions of active organic matter, whether in applications of farm manure, in legume crops, or in grass-root sods of old pastures.

Probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even though plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that with the normal rainfall of Illinois the productive power of the land depends primarily upon the stock of plant food contained in the soil and upon the rate at which it is liberated, just as the success of the merchant depends primarily upon his stock of goods and the rapidity of sales. In both cases the stock of any commodity must be increased or renewed whenever the supply of such commodity becomes so depleted as to limit the success of the business, whether on the farm or in the store.

As the organic matter decays, certain decomposition products are formed, including much carbonic acid, some nitric acid, and various organic acids, and these have power to act upon the soil and dissolve the essential mineral plant foods, thus furnishing nitrates, phosphates, and other salts of potassium, magnesium, calcium, etc. for the use of the growing crop.

As already explained fresh organic matter decomposes much more rapidly than the old humus, which represents the organic residues most resistant to decay and which consequently have accumulated in the soil during the past centuries. The decay of this old humus can be hastened both by tillage, which maintains a porous condition and thus permits the oxygen of the air to enter the soil more freely and to effect the more rapid oxidation of the organic matter, and also by incorporating with the old resistant residues some fresh organic matter, such as farm manure, clover roots, etc., which decay rapidly and which thus furnish or liberate organic matter and inorganic food for bacteria, which, under such favorable conditions appear to have power to attack and decompose the old humus. It is probably for this reason that peat, a very inactive and inefficient fertilizer when used by

itself, becomes much more effective when incorporated with fresh farm manure; so that, when used together, two tons of the mixture may be worth as much as two tons of manure, but if applied separately, the peat has little value. Bacterial action is also promoted by the presence of limestone.

It should be kept in mind that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all plants, only one (hydrogen) from water, and seven from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes), in case the amount liberated from the soil is insufficient; but even these plants (which include only the clovers, peas, beans, and vetches among our common agricultural plants) secure only from the soil six elements (phosphorus, potassium, magnesium, calcium, iron and sulfur), and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Plants are made of these plant-food elements in just the same sense that a building is made of wood and iron, brick, stone, and mortar. Without materials, nothing material can be made. The normal temperature, sunshine, rainfall, and length of season in central Illinois are sufficient to produce 50 bushels of wheat per acre, 100 bushels of corn, 100 bushels of oats, and 4 tons of clover hay; and, where the land is properly drained and properly tilled, such crops would frequently be secured *if the plant foods were present in sufficient amount and liberated at a sufficiently rapid rate to meet the absolute needs of the crops.*

CROP REQUIREMENTS

The accompanying table shows the requirements of such crops for the five most important plant food elements which the soil must furnish. (Iron and sulfur are supplied normally in sufficient abundance compared with the amounts needed by plants, so that they are not known ever to limit the yield of crops):

TABLE A.—PLANT FOOD IN WHEAT, CORN, OATS, AND CLOVER

Produce		Nitrogen, pounds	Phosphorus, pounds	Potassium, pounds	Magnesium, pounds	Calcium, pounds
Kind	Amount					
Wheat, grain........	50 bu.	71	12	13	4	1
Wheat straw..........	2½ tons	25	4	45	4	10
Corn, grain............	100 bu.	100	17	19	7	1
Corn stover......... ..	3 tons	48	6	52	10	21
Corn cobs.............	½ ton	2	..	2	..	..
Oats, grain............	100 bu.	66	11	16	4	2
Oat straw..............	2½ tons	31	5	52	7	15
Clover seed......... ..	4 bu.	7	2	3	1	1
Clover hay........ ...	4 tons	160	20	120	31	117
Total in grain and seed..................		244*	42	51	16	4
Total in four crops		510*	77	322	68	168

*These amounts include the nitrogen contained in the clover seed or hay, which, however, may be secured from the air.

To be sure, these are large yields, but shall we try to make possible the production of yields only half or a quarter as large as these, or shall we set as our ideal this higher mark, and then approach it as nearly as possible with profit? Among the four crops, corn is the largest, with a total yield of more than six tons per acre; and yet the 100-bushel crop of corn is often produced on rich pieces of land in good seasons. In very practical and profitable systems of farming, the Illinois Experiment Station has produced, as an average of the six years, 1905 to 1910, a yield of 87 bushels of corn per acre in grain farming (with limestone and phosphorus applied, and with crop residues and legume crops turned under), and 90 bushels per acre in live-stock farming (with limestone, phosphorus, and manure).

On the Fairfield Experiment Field in Wayne County, on the common prairie land of southern Illinois, yields have been obtained as high as 90 bushels per acre of corn, and 3½ tons of air-dry clover hay.

The importance of maintaining a rich surface soil cannot be too strongly emphasized. It is well illustrated by data from the Rothamsted Experiment Station, the oldest in the world. Thus on Broadbalk field, where wheat has been grown since 1844, the average yields for the ten years, 1892 to 1901 were 12.3 bushels per acre on plot 3 (unfertilized) and 31.8 bushels on plot 7 (well fertilized), but the amounts of both nitrogen and phosphorus in the subsoil (9 to 27 inches) were distinctly greater in plot 3 than in plot 7, thus showing that the higher yields from plot 7 were due to the fact that the plowed soil had been enriched. In 1893, plot 7 contained per acre in the surface soil (0 to 9 inches) about 600 pounds more nitrogen and 900 pounds more phosphorus than plot 3. Even a rich subsoil has little value if it lies beneath a worn-out surface.

METHODS OF LIBERATING PLANT FOOD

Limestone and decaying organic matter are the principal materials the farmer can utilize most profitably to bring about the liberation of plant food.

The limestone corrects the acidity of the soil and thus encourages the development not only of the nitrogen-gathering bacteria which live in the nodules on the roots of clover, cowpeas, and other legumes, but also the nitrifying bacteria which have power to transform the insoluble and unavailable organic nitrogen into soluble and available nitrate nitrogen.

At the same time the products of this decomposition have power to dissolve the minerals contained in the soil, such as potassium and magnesium, and also to dissolve the insoluble phosphate and limestone which may be applied in low-priced forms.

Tillage, or cultivation, also hastens the liberation of plant food by permitting the air to enter the soil and burn out the organic matter; but it should never be forgotten that tillage is wholly destructive, that it adds nothing whatever to the soil, but always leaves the soil poorer. Tillage should be practiced so far as is necessary to prepare a suitable seed-bed for root development and also for the purpose of killing weeds, but more than this is unnecessary and unprofitable in seasons of normal rainfall; and it is much better actually to enrich the soil by proper applications or additions, including limestone and organic matter (both of which have power to improve the physical condition as well as to liberate plant food) than merely to hasten soil depletion by means of excessive cultivation.

PERMANENT SOIL IMPROVEMENT

The best and most profitable methods for the permanent improvement of the common soils of Illinois are as follows:

(1) If the soil is acid apply at least two tons per acre of ground limestone, preferably at times magnesian limestone ($CaCO_3$ $MgCO_3$) which contains both calcium and magnesium, and has slightly greater power to correct soil acidity, ton for ton, than the ordinary calcium limestone ($CaCO_3$); and continue to apply about two tons per acre of ground limestone every four to six years.

(2) Adopt a good rotation of crops, including a liberal use of legumes, and increase the organic matter of the soil either by plowing under the legume crops and other crop residues (straw and corn stalks) or by using for feed and bedding practically all of the crops raised and returning the manure to the land with the least possible loss. No one can say in advance what will prove to be the best rotation of crops, because of variation in farms and farmers, and in prices for produce, but the following are suggested to serve as models or outlines:

First year, corn (with some winter legume, such as red clover, alsike, sweet clover, or alfalfa, or a mixture, seeded on part of the field at the last cultivation).

Second year, oats or barley or wheat (fall or spring) on one part and cowpeas or soybeans where the winter catch crop is plowed down late in the spring.

Third year, wheat or oats (with clover or clover and grass).

Fourth year, clover or clover and grass.

Fifth year, wheat and clover or grass and clover.

Sixth year, clover or clover and grass.

Of course there should be as many fields as there are years in the rotation. In grain farming, with wheat grown the third and fifth years, most of the coarse products should be returned to the soil, and the clover may be clipped and left on the land (only the clover seed being sold the fourth and sixth years); or, in live-stock farming, the field may be used three years for timothy and clover pasture and meadow if desired. The system may be reduced to a five-year rotation by cutting out either the second or the sixth year; and to a four-year system by omitting the fifth and sixth years.

With two years of corn, followed by oats with clover-seeding the third year, and by clover the fourth year, all produce can be used for feed and bedding if other land is available for permanent pasture. Alfalfa may be grown on a fifth field for four or eight years, which is to be alternated with one of the four; or the alfalfa may be moved every five years, and thus rotated over all five fields every twenty-five years.

Other four-year rotations more suitable for grain farming are:

Wheat (and clover), corn, oats, and clover; or corn (and clover), cow-peas, wheat and clover. (Alfalfa may be grown on a fifth field and rotated every five years, the hay being sold.)

Good three-year rotations are:

Corn, oats, and clover; corn, wheat, and clover; or wheat (and clover), corn (and clover), and cow-peas, in which two catch crops and one regular crop of legumes are grown in three years.

A five-year rotation of corn (and clover), cow-peas, wheat, clover, wheat (and clover) allows legumes to be seeded four times, and alfalfa may be grown on a sixth field for five or six years in the combination rotation, alternating between two fields every five years, or rotating over all fields if moved every six years.

To avoid clover sickness it may sometimes be necessary to substitute red clover or alsike for the other in about every third rotation, and at the same time to discontinue their use in the catch-crop mixture. If the corn crop is not too rank, cowpeas or soybeans may also be used as a catch-crop (seeded at the last cultivation) in the southern part of the state and, if necessary to avoid disease, these may well alternate in successive rotations.

For easy figuring it may well be kept in mind that the following amounts of nitrogen are required for the produce named:

1 bushel of oats (grain and straw) requires 1 pound of nitrogen.
1 bushel of corn (grain and stalks) requires 1½ pounds of nitrogen.
1 bushel of wheat (grain and straw) requires 2 pounds of nitrogen.
1 ton of timothy requires 24 pounds of nitrogen.
1 ton of clover contains 40 pounds of nitrogen.
1 ton of cowpeas contains 43 pounds of nitrogen.
1 ton of average manure contains 10 pounds of nitrogen.

The roots of clover contain about half as much nitrogen as the tops, and the roots of cowpeas contain about one-tenth as much as the tops.

Soils of moderate productive power will furnish as much nitrogen to clover (and two or three times as much to cowpeas) as will be left in the roots and stubble. For grain crops, as wheat, corn, and oats, about two-thirds of the nitrogen is contained in the grain and one-third in the straw or stalks.

(3) On all lands deficient in phosphorus (except on those susceptible to serious erosion by surface washing or gullying) apply that element in considerably larger amounts than are required to meet the actual needs of the crops desired to be produced. The abundant information thus far secured shows positively that fine-ground natural rock phosphate can be used successfully and very profitably, and clearly indicates that this material will be the most economical form of phosphorus to use in all ordinary systems of permanent, profitable soil improvement. The first application may well be one ton per acre, and subsequently about one-half ton per acre every four to six years should be applied, at least until the phosphorus content of the plowed soil reaches 2,000 pounds per acre, which may require a total application of from three to five or six tons per acre of raw phosphate containing 12½ percent of the element phosphorus.

Steamed bone meal and even acid phosphate may be used in emergencies, but it should always be kept in mind that phosphorus delivered in Illinois costs about 3 cents a pound in raw phosphate (direct from the mine in carload lots), but 10 cents a pound in steamed bone meal, and about 12 cents a pound in acid phosphate, both of which cost too much per ton to permit their common purchase by farmers in carload lots, which is not the case with limestone or raw phosphate.

Phosphorus once applied to the soil remains in it until removed in crops, unless carried away mechanically by soil erosion. (The loss by leaching is only about 1½ pounds per acre per annum, so that more than 150 years would be required to leach away the phosphorus applied in one ton of raw phosphate.)

The phosphate and limestone may be applied at any time during the rotation, but a good method is to apply the limestone after plowing and work it into the surface soil in preparing the seed bed for wheat, oats, rye, or barley, where clover is to be seeded; while phosphate is best plowed under with farm manure, clover, or other green manures, which serve to liberate the phosphorus.

(4) Until the supply of decaying organic matter has been made adequate, on the poorer types of upland timber and gray prairie soils some temporary benefit may be derived from the use of a soluble salt or mixture of salts, such as kainit, which contains both potassium and magnesium in soluble form and also some common salt (sodium chlorid). About 600 pounds per acre of kainit applied and turned under with the raw phosphate will help to dissolve the phosphorus as well as to furnish available potassium and magnesium, and for a few years such use of kainit will no doubt be profitable on lands deficient in organic matter, but the evidence thus far secured indicates that its use is not absolutely necessary and that it will not be profitable after adequate provision is made for decaying organic matter, since this will necessitate returning to the soil either all produce except the grain (in grain farming) or the manure produced in live-stock farming. (Where hay or straw are sold, manure should be bought.)

On soils which are subject to surface washing, including especially the yellow silt loam of the upland timber area, and to some extent the yellow-gray silt loam, and other more rolling areas, the supply of minerals in the subsurface and subsoil (which gradually renew the surface soil) tend to provide for a low-grade system of permanent agriculture if some use is made of legume plants, as in long rotations with much pasture, because both the minerals and nitrogen are thus provided in some amount almost permanently; but where such lands are farmed under such a system not more than two or three grain crops should be grown during a period of ten or twelve years, the land being kept in pasture most of the time; and where the soil is acid a liberal use of limestone, as top dressings if necessary, and occasional reseeding with clovers will benefit both the pasture and indirectly the grain crops.

ADVANTAGE OF CROP ROTATION AND PERMANENT SYSTEMS

It should be noted that clover is not likely to be well infected with the clover bacteria during the first rotation on a given farm or field where it has not been grown before within recent years; but even a partial stand of clover the first time will probably provide a thousand times as many bacteria for the next clover crop as one could afford to apply in artificial inoculation, for a single root-tubercle may contain a million bacteria developed from one during the season's growth.

This is only one of several advantages of the second course of the rotation over the first course. Thus the mere practice of crop rotation is an advantage, especially in helping to rid the land of insects and foul grass and weeds. The deep-rooting clover crop is an advantage to subsequent crops because of that characteristic. The larger applications of organic manures (made possible by the larger crops) are a great advantage; and in systems of permanent soil improvement, such as are here advised and illustrated, more limestone and more phosphorus are provided than are needed for the meager or moderate crops produced during the first rotation, and consequently the crops in the second rotation have the advantage of such accumu-

lated residues (well incorporated with the plowed soil) in addition to the regular applications made during the second rotation.

This means that these systems tend positively toward the making of richer land. The ultimate analyses recorded in the Tables give the absolute invoice of these Illinois soils. They show that most of them are positively deficient only in limestone, phosphorus, and nitrogenous organic matter; and the accumulated information from careful and long-continued investigations in different parts of the United States clearly establish the fact that in general farming these essentials can be supplied with greatest economy and profit by the use of ground natural limestone, very finely ground natural rock phosphate, and legume crops to be plowed under directly or in farm manure. On normal soils no other applications are absolutely necessary, but, as already explained, the addition of some soluble salt in the beginning of a system of improvement on some of these soils produces temporary benefit, and if some inexpensive salt such as kainit is used it may produce sufficient increase to more than pay the added cost.

The Potassium Problem

As reported in Illinois Bulletin 123, where wheat has been grown every year for more than half a century at Rothamsted, England, exactly the same increase was produced (5.6 bushels per acre), as an average of the first 24 years, whether potassium, magnesium, or sodium was applied, the rate of application per annum being 200 pounds of potassium sulfate and molecular equivalents of magnesium sulfate and sodium sulfate. As an average of 59 years (1852 to 1910) the yield of wheat has been 12.7 bushels on untreated land, 23.3 bushels where 86 pounds of nitrogen and 29 pounds of phosphorus per acre per annum were applied; and, as further additions, 85 pounds of potassium raised the yield to 31.3 bushels; 52 pounds of magnesium raised it to 29.3 bushels; and 50 pounds of sodium raised it to 29.5 bushels. Where potassium was applied the average wheat crop removed 40 pounds of that element in the grain and straw, or three times as much as would be removed in the grain only for such crops as are suggested in Table A. The Rothamsted soil contained abundance of limestone, but no organic matter was provided except the little in the stubble and roots of the wheat plants.

On another field at Rothamsted the average yield of barley for 59 years (1852 to 1910) has been 14.4 bushels on untreated land, 38.6 bushels where 43 pounds of nitrogen and 29 pounds of phosphorus have been applied per acre per annum; while the further addition of 85 pounds of potassium, 19 pounds of magnesium, and 14 pounds of sodium (all in sulfates) raised the average yield to 41.7 bushels, but, where only 70 pounds of sodium were applied in addition to the nitrogen and phosphorus, the average has been 43.3 bushels. Thus, as an average of 59 years, the use of sodium produced 1.8 bushels less wheat and 1.6 bushels more barley than the use of potassium, with both grain and straw removed and no organic manures returned.

In recent years the effect of potassium is becoming much more marked than that of sodium or magnesium, on the wheat crop; but this must be expected to occur in time where no potassium is returned in straw or manure, and no provision made for liberating potassium from the supply still remaining in the soil. If more than three-fourths of the potassium removed were returned in the straw (see Table A), and if the decomposi-

tion products of the straw have power to liberate additional amounts of potassium from the soil, the necessity of purchasing potassium in a good system of farming on such land is very remote.

While about half of the potassium, nitrogen, and organic matter, and about one-fourth of the phosphorus, contained in manure, will be lost by three or four months' exposure in the ordinary pile in the barn yard, there is practically no loss if plenty of absorbent bedding is used on cement floors, and if the manure is hauled to the field and spread within a day or two after it is produced. Again, while the animals destroy two-thirds of the organic matter and retain one-fourth of the nitrogen and phosphorus in average live-stock farming, they retain less than one-tenth of the potassium, from the food consumed; so that the actual loss of potassium in the products sold from the farm, either in grain farming or in live-stock farming, is wholly negligible on land containing 25,000 pounds or more of potassium in the surface 6⅔ inches.

The removal of one inch of soil per century by surface washing (which is likely to occur wherever there is satisfactory surface drainage and frequent cultivation) would permanently maintain the potassium in grain farming by renewal from the subsoil, provided one-third of the potassium is removed by cropping before the soil is carried away.

From all of these facts it will be seen that the potassium problem is not one of supply but of liberation; and the Rothamsted records show that for many years other soluble salts have practically the same power as potassium to increase crop yields in the absence of sufficient decaying organic matter. Whether this action relates to supplying or liberating potassium for its own sake, or to the power of the soluble salt to increase the availability of phosphorus or other elements, it is not known, but where much potassium is removed, as in the entire crops at Rothamsted with no return of organic residues, probably the soluble salt functions in both ways.

As an average of 112 separate tests conducted in 1907, 1908, 1909 and 1910, on the Fairfield Experiment Field, an application of 200 pounds of potassium sulfate, containing 85 pounds of potassium costing $5.10, increased the yield of corn by 9.3 bushels per acre; while 600 pounds of kainit, containing only 60 pounds of potassium and costing $4.00, gave an increase of 10.7 bushels. Thus, at 40 cents a bushel for corn, the kainit has paid for itself; but these results, like those at Rothamsted, were secured where no adequate provision had been made for decaying organic matter.

Additional experiments at Fairfield include an equally complete test with potassium sulfate and kainit on land to which 8 tons per acre of farm manure had been applied. As an average of 112 tests with each material, the 200 pounds of potassium sulfate increased the yield of corn by 1.7 bushels, while the 600 pounds of kainit also gave an increase of 1.7 bushels. Thus, where organic manure was supplied, very little effect was produced by the addition of either potassium sulfate or kainit; in part perhaps because the potassium removed in the crops is mostly returned in the manure if properly cared for: and perhaps in larger part because the decaying organic matter helps to liberate and hold in solution other plant food elements, especially phosphorus.

In laboratory experiments at the Illinois Experiment Station, it has been shown that potassium salts and most other soluble salts increase the solubility of the phosphorus in soil and in rock phosphate as determined by chemical analysis; also that the addition of glucose with rock phosphate in

pot-culture experiments increases the availability of the phosphorus, as measured by plant growth, altho the glucose consists only of carbon, hydrogen, and oxygen, and thus contains no plant food of value.

If we remember that, as an average, live stock destroy two-thirds of the organic matter of the food consumed, it is easy to determine from Table A that more organic matter will be supplied in a proper grain system than in a strictly live-stock system; and the evidence thus far secured from older experiments at the University and at other places in the state indicates that if the corn stalks, straw, clover, etc., are incorporated with the soil as soon as practicable after they are produced (which can usually be done in the late fall or early spring), there is little or no difficulty in securing sufficient decomposition in our humid climate to avoid serious interference with the capillary movement of the soil moisture, a common danger from plowing under too much coarse manure of any kind in the late spring of a dry year.

If, however, the entire produce of the land is sold from the farm, as in hay farming, or when both grain and straw are sold, of course the draft on potassium will then be so great that in time it must be renewed by some sort of application. As a rule, such farmers ought to secure manure from town, since they furnish the bulk of the material out of which the manure is produced.

CALCIUM AND MAGNESIUM

When measured by the actual crop requirements for plant food, magnesium and calcium are more limited in some Illinois soils than potassium. But with these elements we must also consider the loss by leaching. As an average of 90 analyses* of Illinois well-waters drawn chiefly from glacial sands, gravels, or till, 3 million pounds of water (about the average annual drainage per acre for Illinois) contained 11 pounds of potassium, 130 of magnesium, and 330 of calcium. These figures are very significant, and it may be stated that if the plowed soil is well supplied with the carbonates of magnesium and calcium, then a very considerable proportion of these amounts will be leached from that stratum. Thus the loss of calcium from the plowed soil of an acre at Rothamsted, England, where the soil contains plenty of limestone, has averaged more than 300 pounds a year as determined by analyzing the soil in 1865 and again in 1905. And practically the same amount of calcium was found by analyzing the Rothamsted drainage waters.

It is of interest to note that thirty crops of clover of four tons each would require 3,510 pounds of calcium, while the most common prairie land of southern Illinois contains only 3,420 pounds of total calcium in the plowed soil of an acre. (See Soil Report No. 1.) Thus limestone has a positive value on some soils for the plant food which it supplies, in addition to its value in correcting soil acidity and in improving the physical condition of the soil. Ordinary limestone (abundant in the southern and western parts of the State) contains nearly 800 pounds of calcium per ton; while a good grade of dolomitic limestone (the more common limestone of northern Illinois) contains about 400 pounds of calcium and 300 pounds of magnesium per ton. Both of these elements are furnished in readily available form in ground dolomitic limestone.

*Reported by Doctor Bartow and associates, of the Illinois State Water Survey.

UNIVERSITY OF ILLINOIS
Agricultural Experiment Station

SOIL REPORT NO. 3

HARDIN COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER,
J. H. PETTIT AND J. E. READHIMER

URBANA, ILLINOIS, AUGUST, 1912

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C. C. Logan, Associate

*On leave.

HARDIN COUNTY SOILS

BY CYRIL G. HOPKINS, J. G. MOSIER, J. H. PETTIT AND J. E. READHIMER

INTRODUCTION

The counties of Hardin, Pope, Johnson, Union, Alexander, Pulaski and Massac include most of the unglaciated area of southern Illinois. The Ozark Hills extend across this area from west to east, and in places project into the next tier of counties on the north. The hill lands represent the most extensive soil types in these seven counties, altho the bottom lands are also very important, and quite extensive in the southern portion, including the Mississippi, Ohio, Cash and Big Bay bottoms.

Hardin county is representative of the unglaciated area in southern Illinois, but the information contained in this report on "Hardin County Soils" is applicable not only to the other counties in this area, but also to the hill lands in the lower Illinoisan glaciation lying between the Ozark Hills and the corn belt; and even in the corn-belt counties there are some hill lands, especially near the larger streams, whose chief difference from the Ozark Hills is the lower degree of acidity in the northern soils.

For information concerning the soils of the prairie counties of the wheat belt of Illinois, the reader is referred to Soil Report No. 1, "Clay County Soils"; and for information concerning most of the important soil types of the corn belt, he is referred to Soil Report No. 2, "Moultrie County Soils." In addition it may be stated that Bulletin 123, "The Fertility in Illinois Soils," shows the great soil areas of the state and gives the composition of the most important soil types in each area and much information relating to their improvement.

SOIL FORMATION

Hardin county is situated in the southeastern part of the state on the Ohio river, entirely within the unglaciated area. The altitude above sea level varies from slightly over 300 feet to more than 800 feet, thus giving a relief of 500 feet in the county, the topography over almost the entire county being characterized by hills and valleys. As a result of the topography and of the somewhat heavy rainfall, water has been and is now a very active agent in soil formation or modification.

The chief material composing the soils of Hardin county is a wind-blown dust known as loess. Altho the county has never been glaciated it has no purely residual soil formed by the disintegration and partial decomposition

of rocks in place, the residual material having been buried beneath the deposit of loess to a depth of 5 to 20 feet, altho on some of the stony slopes the soil is a mixture of residual and wind-blown material, and might properly be called residuo-loessial or residuo-aeolial soil.

The following table gives the soil types, the areas in acres and square miles, and the percentage of each type of total area in the county.

TABLE 1.—SOIL TYPES OF HARDIN COUNTY

Soil type No.	Names	Area in square miles	Area in acres	Percent of total
	(a) Upland Timber Soils (page 13)			
135	Yellow silt loam	120.15	76,896.0	70.56
134	Yellow-gray silt loam	10.50	6,720.0	6.17
864	Yellow fine sandy loam	.46	294.4	.27
198	Stony loam	17.05	10,912.0	10.01
199	Rock outcrop	3.58	2,291.2	2.10
	(b) Swamp and Bottom-land Soils (page 18)			
1323	Red-brown clay loam	3.16	2,022.4	1.86
1331	Deep gray silt loam	1.20	768.0	.66
1361.1	Mixed fine sandy loam	12.61	8,070.4	7.40
1380	River sand	.20	130.5	.12
	(c) Terrace Soils (page 20)			
1516	Gray clay	.31	195.8	.17
1530	Gray silt loam on tight clay	1.18	755.2	.63
	Totals	170.40	109,055.9	100.00

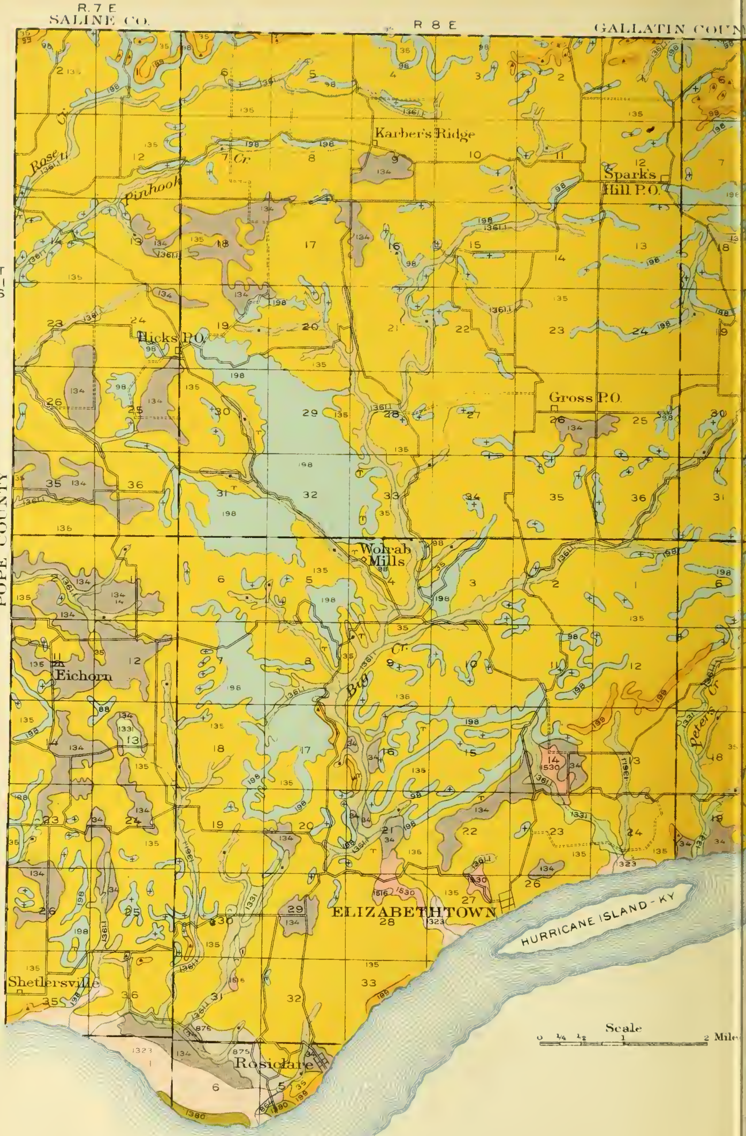
THE INVOICE AND INCREASE OF FERTILITY IN HARDIN COUNTY SOILS

SOIL ANALYSIS

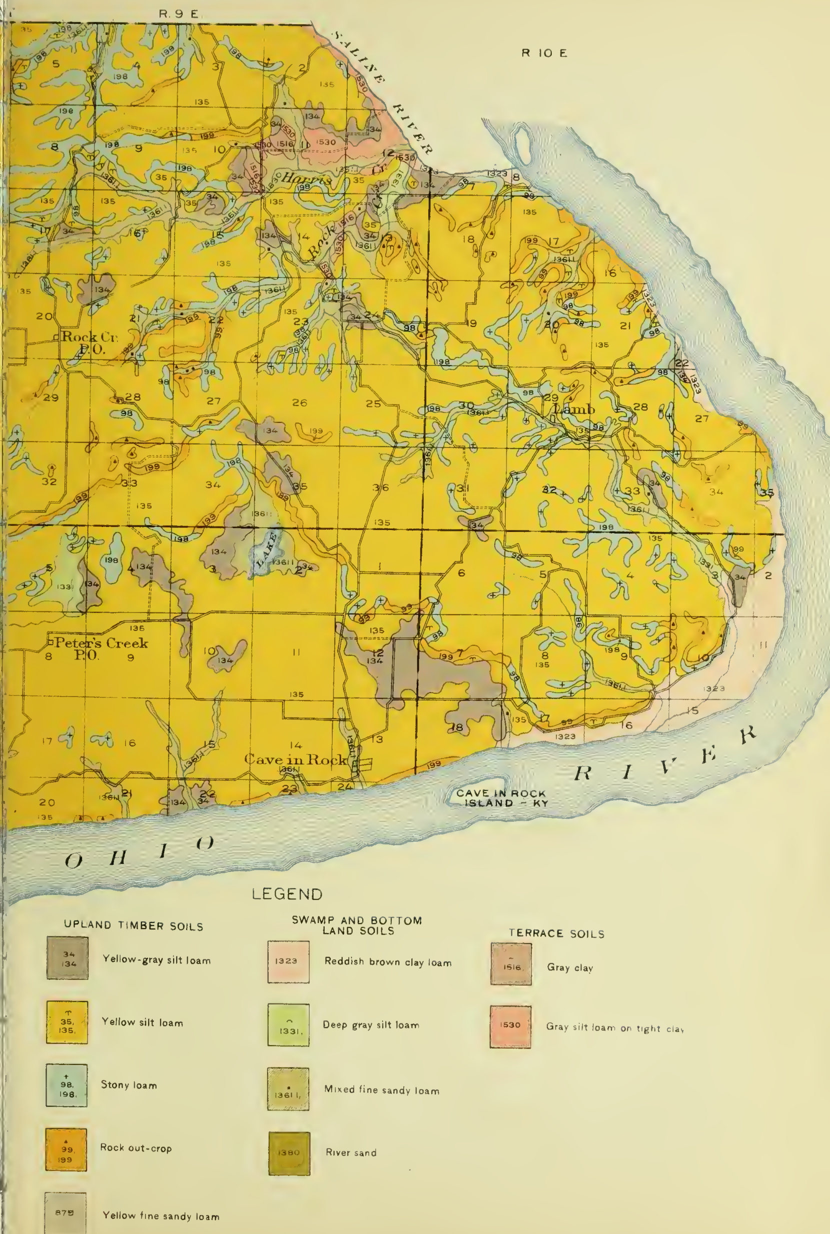
To appreciate the value of the essential elements of fertility for crops, we should keep in mind that food for plants is just as important as food for animals. In the Appendix will be found a more comprehensive discussion of this general subject, which should be read and studied in advance by those who are not familiar with the fundamental principles involved; and in any case the reader should carry in mind the plant food requirements for crops and the loss of plant food from soils by leaching. (See Table A and the closing pages of the Appendix.)

In brief, all agricultural plants are composed of ten elements of plant food, of which two (carbon and oxygen) are secured from the air, one (hydrogen) from water, and seven (nitrogen, phosphorus, potassium, magnesium, calcium, iron, and sulfur) are taken from the soil. Legume crops, such as the clovers, peas, and beans, may, under suitable conditions, secure more or less of their nitrogen from the air in case the amount furnished by the soil is insufficient. The supply of iron in soils is so great that it need not be further considered, and so far as we know the supply of sulfur in the soil, supplemented by the sulfur brought to the soil in rain and otherwise, is sufficient to meet all requirements of common farm crops for that element.

We need to give special consideration to the five elements nitrogen, phosphorus, potassium, magnesium, and calcium, and in addition we should not only provide against soil acidity, but insure the presence of limestone.



SOIL SURVEY MAP OF HARDIN COUNTY
UNIVERSITY OF ILLINOIS AGRICULTURAL EXPERIMENT STATION


R. 9 E.
R 10 E
SALINE RIVER
Harris Cr.
Rock Cr.
Rock Cr. P.O.
Lamb
LAKE
Peter's Creek P.O.
Cave in Rock
CAVE IN ROCK ISLAND - KY
OHIO RIVER
LEGEND
UPLAND TIMBER SOILS
34 134 Yellow-gray silt loam
35, 135, Yellow silt loam
98, 198, Stony loam
99, 199 Rock out-crop
875 Yellow fine sandy loam
SWAMP AND BOTTOM LAND SOILS
1323 Reddish brown clay loam
1331, Deep gray silt loam
1361 I, Mixed fine sandy loam
1380 River sand
TERRACE SOILS
1516 Gray clay
1530 Gray silt loam on tight clay

In Table 1 are recorded the average amounts of these important elements per acre to a depth of 6⅔ inches for all of the different types of soil in Hardin county. The table also shows the amount of limestone, if present, or the amount of limestone required to neutralize or destroy the acidity present. The organic carbon is the best measure of the organic matter (partially decayed vegetable matter); and, as explained in the Appendix, the ratio of carbon to nitrogen gives some indication of the age or condition of the organic matter. Approximately one-half of the organic matter of the soil is carbon, so that 12,880 pounds of carbon, for example, correspond to about 12 tons per acre of organic matter.

Two million pounds per acre (about 6⅔ inches deep) represents at least as much soil as is ordinarily turned in plowing. This is the soil with which we finally incorporate the farm manure, phosphate, limestone, or other fertilizer applied to the soil; and this is the soil stratum upon which we must depend in large part to furnish the necessary plant food for the production of the common crops, as will be better understood from the information given in the Appendix. As there stated, even a rich subsoil has but little value if it lies beneath a worn-out surface. If, however, the surface soil is enriched, the strong, vigorous plants will have power to secure more plant food from the subsurface and subsoil than would be the case with weak, shallow-rooted plants.

TABLE 2.—FERTILITY IN THE SOILS OF HARDIN COUNTY, ILLINOIS
Average pounds per acre in 2 million pounds of surface soil (about 0 to 6⅔ inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone required
	Upland Timber Soils								
135	Yellow silt loam	12880	1250	840	34200	7710	3980		2100
134	Yellow-gray silt loam	15600	1520	870	29150	5510	4390		40
864	Yellow fine sandy loam...	14180	1300	780	30760	5360	4620	500	
198	Stony loam (virgin).......	15600	840	480	25040	3420	4300		1520
	Swamp and Bottom-land Soils								
1323	Red-brown clay loam..........	32320	3090	1830	41200	11780	6430	2390	
1331	Deep gray silt loam..........	12920	1100	580	26580	4860	5860	660	
1361.1	Mixed fine sandy loam...	13900	1290	650	29480	4990	4910	840	
1380	River sand.....	11100	520	920	18740	5720	10420	21620	
	Terrace Soils								
1516	Gray clay	37160	3280	1260	39220	12560	11860	1020	
1530	Gray silt loam on tight clay.	39280	3360	1440	41860	11880	6360		260

By comparing the data in Table 1 with those in Table A in the Appendix, the relative supply of the different essential elements of plant food is very easily determined. Thus the surface soil of an acre of the yellow silt loam (the most extensive soil type in Hardin county, covering most of the ordinary hill land) contains only 1250 pounds of total nitrogen, while the

grain crops suggested in Table A would remove from the soil 343 pounds during one rotation; and the total nitrogen in the plowed soil (if 6⅔ inches deep) would meet the requirements of only eight such crops of corn as ought to be grown under the average climatic conditions of southern Illinois. The ratio of carbon to nitrogen (about 10 to 1) shows that the organic matter is very inactive, and consequently that the liberation of nitrogen will not be rapid. The other upland soils of the county are not much better supplied with nitrogen; and too great emphasis cannot be laid upon the importance of growing legume crops, such as alfalfa, clover, cowpeas and soybeans, which if infected with the proper nitrogen-fixing bacteria have free access to the inexhaustible supply of nitrogen in the air.

On the other hand, there are some difficulties to be met and overcome if the most valuable legume crops are to be grown satisfactorily on these lands. Thus, all of these upland soils are markedly sour and consequently they not only contain no limestone, but require applications of that material to correct the acidity present.

The only exception to this is the small area of yellow fine sandy loam near Rosiclare, and even this is strongly acid in the subsurface and sub-

PLATE 1. WHEAT IN POT CULTURES; YELLOW SILT LOAM SOIL OF HILL LAND.

soil, the small amount of limestone in the surface soil probably being due to the recent additions of dust blown from the great area of river bed to the east and southwest, which is exposed to the action of the wind when the river is low, occasionally for weeks at a time. Even this soil should receive liberal applications of ground limestone.

RESULTS FROM POT-CULTURE EXPERIMENTS

The plant food element which limits the yield of cereal crops on the common upland soil is nitrogen. This fact is very strikingly illustrated by the results from pot-culture experiments reported in Table 3, and shown photographically in Plate 1.

A large quantity of the typical worn hill soil was collected from two different places. Each lot of soil was thoroly mixed and ten 4-gallon jars were filled with it. Ground limestone was added to all except the first and last jars in each set, those two being retained as control or check plots. The elements nitrogen, phosphorus, and potassium were added singly and in combination, as plainly indicated in Table 3.

TABLE 3.—CROP YIELDS IN POT-CULTURE EXPERIMENTS ON YELLOW SILT LOAM HILL LAND SOIL

Pot No.	Soil treatment applied	Wheat yields (grams per pot)	Oat yields (grams per pot)
1	None	3	5
2	Limestone	4	4
3	Limestone, nitrogen	26	45
4	Limestone, phosphorus	3	6
5	Limestone, potassium	3	5
6	Limestone, nitrogen, phosphorus	34	38
7	Limestone, nitrogen, potassium	33	46
8	Limestone, phosphorus, potassium	2	5
9	Limestone, nitrogen, phosphorus, potassium	34	38
10	None	3	5
	Average yield with nitrogen	32	42
	Average yield without nitrogen	3	5
	Average gain for nitrogen	29	37

As an average the nitrogen applied produced about eight times as much as the yield secured without the addition of nitrogen. While there are some variations in yield which are due, of course, to differences in the individuality of seed or other uncontrolled cause, yet there is no doubting the plain lesson taught by these actual trials with growing plants. Thus, both the soil analysis and the culture experiment agree in showing that the element nitrogen must be provided for the improvement of this soil.

The next question is, Where is the farmer to secure this much needed nitrogen? To purchase it in commercial fertilizer would cost too much. Indeed, the cost of the nitrogen in such fertilizers is greater than the value of the increase in crop yields, under average conditions. On the other hand, there is no need whatever to purchase it, because the air contains an inexhaustible supply of nitrogen, and under suitable conditions this can be obtained by the farmer direct from the air, not only without cost, but with profit in the getting; for clover, alfalfa, cowpeas and soybeans have power to secure atmospheric nitrogen, provided the soil contains limestone and the proper nitrogen-fixing bacteria; and these crops are worth raising for their own sake.

In order to get further information along this line an experiment with pot cultures was conducted for several years, with the results reported in Table 4, the same worn hill soil being used. To three of the pots (Nos. 3, 6 and 9) nitrogen was applied in commercial form, and at an expense amounting to more than the total value of the crops produced. In three other pots (Nos. 2, 11 and 12) a crop of cowpeas was grown during the late summer and fall, and these were turned under before planting wheat or oats. Pots 1 and 8 serve for important comparisons.

After the second catch crop of cowpeas had been turned under, the yield from Pot 2 exceeded that from Pot 3; and in the subsequent years the legume green manures produced, as an average, rather better results than the commercial nitrogen. These experiments confirm those reported in Table 3, in showing the very great need of nitrogen for the improvement of this soil; and they also show that the nitrogen need not be purchased, but that it can be obtained from the air by growing legume crops and plowing

them under as green manure. Of course, the legume crops could be fed to live stock and the resulting farm manure returned to the land; but this practice is not so good for the soil, altho it may sometimes be more profitable; and if sufficiently frequent crops of legumes are grown and if the farm manure produced is sufficiently abundant, and is saved and applied with care, this soil can be very markedly improved by live-stock farming, as well as by green manuring.

PLATE 2. WHEAT IN POT CULTURES; YELLOW SILT LOAM SOIL OF WORN HILL LAND.

TABLE 4.—CROP YIELDS IN POT CULTURES, INCLUDING NITROGEN-FIXING GREEN MANURE CROPS: YELLOW SILT LOAM HILL LAND (Grams per Pot)

Pot No.	Soil treatment	1903 Wheat	1904 Wheat	1905 Wheat	1906 Wheat	1907 Oats
1	None	5	4	4	4	6
2	Limestone, legume	10	17	26	19	37
11	Limestone, legume, phosphorus	14	19	20	18	27
12	Limestone, legume, phosphorus, potassium	16	20	21	19	30
3	Limestone, nitrogen	17	14	15	9	28
6	Limestone, nitrogen, phosphorus	26	20	18	18	30
9	Limestone, nitrogen, phosphorus, potassium	31	34	21	20	26
8	Limestone, phosphorus, potassium	3	3	5	3	7

RESULTS FROM FIELD EXPERIMENTS AT VIENNA

In 1902 a soil experiment field was established on the worn hill land of southern Illinois, near Vienna, in Johnson county; and the results of nine years' experiments under field conditions are reported in Table 5.

This field includes three divisions, or series, with five plots in each series. A three-year rotation of wheat, corn, and cowpeas was begun on this field, but because of local interest this was changed to corn, wheat, and clover. When the clover failed, which was frequent, cowpeas were substituted.

During the first three years the entire crop of cowpeas was plowed under, except on Plot 1, as indicated in Table 5. During the second three years all crops were removed; and during the third three-year period the pods of the compeas (small yields not threshed), and all grain were harvested and removed, while the pea vines or clover, and the wheat straw and corn stalks were returned to the land (except on Plot 1, from which all crops were re-

moved and nothing returned). Thus, the "crop residues" were returned in part during the first period, not at all during the second period, and completely only during the third period; and the effect of plowing under all crop residues during one rotation upon the crop yields of the next rotation is not yet shown on this field.

If we pass over the first three years required to get the rotation and soil treatment underway, we still have the records of six years, during which time 6 crops of corn, 6 crops of wheat, and 1 crop of clover hay were harvested and weighed. A study of Table 5 will show that the land treated with ground limestone and some crop residues (Plot 3) produced, during the six years, 74 bushels more corn, 60 bushels more wheat, and 1¼ tons more hay than the untreated land.

It should be kept in mind that the figures showing increase in crop yields constitute the real data upon which all subsequent computations must be based. The work of the investigator is to conduct the experiment and secure the data; while the farmer and landowner has the right to use any prices he can justify for his locality and conditions, and these prices will vary greatly, not only in different years and seasons, but also in different localities. Thus the average price of corn in southern Illinois is probably 10 cents a bushel higher than in the corn belt, except in an occasional year when southern Illinois may produce an extra good crop and have a surplus to be shipped out.

As a rule the farmer is inclined to calculate the value of the increase in crop yields at the prevailing prices; while the computations usually made by the Experiment Station are much more conservative. At current prices for produce, say 60 cents a bushel for corn, 90 cents for wheat, and $15 a ton for hay, the increase in money value from the use of limestone on the Vienna field would amount to $117, which is $39 per acre for the six years, or $6.50 per acre per annum above the returns for the same crops from the untreated land.

By comparing Plots 2 and 3, it will be found that the land treated with limestone produced, during the same six years, 64 bushels more corn, 39 bushels more wheat, and 1.1 tons more harvested hay than the land otherwise treated the same. At the prices mentioned these increases amount to $90 from three acres, or $30 from one acre, which is $5.00 an acre for each year. This is about ten times the necessary average annual expense for ground limestone in permanent systems. Thus, long-continued investigations have shown that 800 pounds per acre is about the average annual loss of limestone. At $1.25 per ton, this would cost 50 cents per acre per annum.

These figures indicate a possible gross return of about $10 for every $1.00 necessarily invested in ground limestone for the improvement of this soil, which represents by far the most extensive soil type in the seven southernmost counties of Illinois. Some will probably insist that the prices and computations used above are reasonable and fair; and if present prices continue, it is possible that investment in ground limestone may ultimately pay such returns if the seed of the legume crops are harvested and if the full system of manuring with crop residues and catch crops is followed in the best crop rotation; but in Table 5 we have presented the more conservative figures.

In order to summarize the results of the nine years' experiments, the six grain crops from each series and the one crop of clover hay harvested

from the 200 series (in 1907) are reduced to a money basis, in which corn is figured at 35 cents a bushel, oats at 30 cents, wheat at 70 cents, and hay at $6.00 a ton. These low prices are used in order to avoid any possible exaggeration of the value of the increase produced by the soil treatment applied. The prices are appreciably below the ten-year averages for Illinois, but it should be kept in mind that the increase produced by soil treatment is not delivered at the market by that treatment, but only ready for the harvest; and additional expense is required for harvesting, threshing, baling and storing or marketing. The yields are all given, and anyone can compute the value of the increase at any other prices, if desired.

About 9 tons per acre of ground limestone were applied in 1902. The cost of this is figured at $1.25 per ton. This is somewhat above the average cost in southern Illinois.

The phosphorus was supplied at the rate of 25 pounds per acre per annum in 200 pounds of steamed bone meal, applied at the rate of 600 pounds every three years. It is figured at 10 cents a pound for phosphorus, or at $25 a ton for steamed bone. The average cost of steamed bone is now somewhat higher; and where farm manure or green manure is available we advise using raw rock phosphate in place of steamed bone, the raw phosphate being just as rich in phosphorus and costing in southern Illinois less than $8.00 per ton in carload lots.

The potassium was applied at the rate of 42 pounds per acre per annum in 100 pounds of potassium sulfate. The potassium sulfate is figured at $50 per ton, or potassium at 6 cents a pound. As shown in Table 2, this common upland contains, as an average, more than 30,000 pounds of potassium in the plowed soil of an acre (6⅔ inches deep), and the subsurface and subsoil are still richer, so that the potassium problem is not one of addition but of liberation; and, if potassium salts are applied at all or temporarily, until more vegetable matter can be grown and plowed under, then we would recommend the use of kainit in larger amounts and at less expense, rather than potassium sulfate, for reasons explained in the Appendix.

It should be understood that when these field experiments were begun, we had but very little information concerning the composition or requirements of Illinois soils. We used steam bone meal and potassium sulfate to find out if the soil needed phosphorus or potassium. It was known that these materials furnish those elements in good form. On many experiment fields established more recently we are now using fine-ground rock phosphate with very good results, and in some cases we are also making trials with kainit. (See Soil Reports Nos. 1 and 2 and Circulars 116, 127, 149, and 157.)

Taking into account the entire period of nine years, it will be seen that, at most conservative prices, the ground limestone has already paid back nearly twice its actual cost, and the equivalent of about one-half of the limestone still remains in the soil for the benefit of future crops.* It is

*On the Edgewood experiment field in Effingham county 10 tons per acre of ground limestone were applied in 1902. At the end of ten years the analysis of the soil showed that 8,370 pounds of limestone still remained in the surface stratum, as the average of eight treated plots; while the acidity of the subsurface of the same plots averaged 2770 pounds less (in terms of limestone required to neutralize it) than the average of eight untreated half plots, and the acidity in the surface soil of the untreated land corresponded to 1070 pounds of limestone required. Thus the total difference at the end of ten years is equivalent to 6.1 tons of calcium carbonate, and the net loss has been 3.9 tons of limestone, or 780 pounds per acre per annum. (These averages are based upon analyses involving twenty-four determinations, which were made by Mr. C. F. Ferris, B.S., as part of his work for the degree of Master of Science in Agronomy, 1912.)

TABLE 5.—CROP YIELDS PER ACRE ON VIENNA EXPERIMENT FIELD, ON COMMON WORN HILL LAND: YELLOW SILT LOAM, UNGLACIATED

Soil treatment	None (except rotation)	Crop residues	Crop residues and limestone	Crop residues, limestone, phosphorus	Residues, limestone, phosphorus, potassium
Plot No	101	102	103	104	105
1902 Corn, bu	15.5	13.3	14.9	12.5	19.9
1903 Corn, bu	9.3	5.0	8.3	7.4	11.6
1904 Cowpeas	removed	turned	turned	turned	turned
1905 Wheat, bu	1.3	10.8	18.2	25.6	30.0
1906 Cowpeas	removed	removed	removed	removed	removed
1907 Corn, bu	16.7	17.8	30.3	37.1	38.1
1908 Wheat, bu	0	0	4.5	8.3	9.8
1909 Cowpeas	removed	turned	turned	turned	turned
1910 Corn, bu	33.5	35.4	44.7	46.6	58.3
Value of six crops	$27.16	$32.59	$50.26	$59.99	$72.63
Increase over Plot 2			$17.67	$27.40	$40.04
Plot No	201	202	203	204	205
1902 Oats, bu	19.1	18.8	19.8	20.0	31.7
1903 Cowpeas	removed	turned	turned	turned	turned
1904 Wheat, bu	6.7	7.1	10.0	14.8	17.5
1905 Corn, bu	37.5	42.9	61.9	57.2	56.5
1906 Wheat, bu	3.8	5.4	17.9	11.3	15.0
1907 Clover, tons	.65	.81	1.92	2.56	2.23
1908 Corn, bu	35.2	35.6	43.9	42 9	50.6
1909 Wheat, bu	4.6	6.8	9.6	12.8	11.3
1910 Clover	removed	turned	turned	turned	turned
Value of seven crops	$45.65	$51.49	$80.74	$83.63	$91.04
Increase over Plot 2			$29.25	$32.14	$39 55
Plot No	301	302	303	304	305
1902 Cowpeas	removed	turned	turned	turned	turned
1903 Wheat, bu	.4	.6	.7	8.0	11.0
1904 Corn, bu	30.5	35.5	49.1	49.4	44.7
1905 Cowpeas	removed	removed	removed	removed	removed
1906 Corn, bu	41.2	40.6	48.9	40.9	40.9
1907 Wheat, bu	4.3	6.1	13.0	13.6	15.6
1908 Cowpeas	removed	turned	turned	turned	turned
1909 Corn, bu	23.0	24.9	31.3	32 6	33.5
1910 Wheat, bu	3.1	8.7	13.7	14.4	14.6
Value of six crops	$38.61	$46.13	$64.44	$68.22	$70.53
Increase over Plot 2			$18.31	$22.09	$24 40
Average of three series	$37.14	$43.40	$65.14	$70.61	$78.06
Increase over Plot 2			$21.74	$27.21	$34 66
Cost of treatment			$11.25	$33.75	$56.25

possible, too, that half the quantity of limestone applied at the beginning would have given nearly or quite as good results, but the information available is not conclusive as to the initial amount of limestone to apply for the most profitable results. In any case the initial application should be considered as an investment to be added to the value of the land, while the cost of subsequent necessary applications should be calculated in the annual expense.

On this rolling hill land, the addition of $22.50 worth of steamed bone meal has increased the crop values by only $5.47 in nine years; and the further addition of $22.50 in potassium sulfate has produced only $7.45 increase in the value of the crops harvested, at the prices used for the increase in yields.

Whether a much larger use of organic manures will ultimately increase the nitrogen content of the soil to a point where phosphorus can be applied with profit on these hill lands, subject to rather serious surface washing, seems somewhat doubtful; and, considering the fact that such an increase in decaying organic matter will largely increase the liberation of potassium from the enormous supply contained in the soil, it seems even more doubtful if the addition of potassium will ever be advisable in permanent systems of general farming.

Both the pot cultures and the field experiments agree in showing that nitrogen is by far the most limiting element and that this can be secured from the air by legume crops where liberal use is made of ground limestone to correct the acidity of the soil; and of course the limestone also furnishes the element calcium, the supply of which in this soil is but little more than one-tenth as great as the supply of potassium, while the combined loss by leaching and cropping is nearly ten times greater with calcium than with potassium, as is more fully explained in the Appendix. As plant food, calcium is especially important for such crops as clover. (See Table A in the Appendix.)

RESULTS FROM FIELD EXPERIMENTS AT RALEIGH

The Raleigh experiment field, in Saline county, is located on the gently undulating timber land (yellow-gray silt loam), which is also the second most important upland soil type in Hardin county.

Six tons per acre of ground limestone were applied to certain plots on the Raleigh field in the fall of 1909; and as an average of the next two years (1910 and 1911) the limestone increased the yields per acre on one set of plots by 3.9 bushels of wheat, by .40 ton of hay (cowpeas or clover), by 14.1 bushels of oats, and by 13.4 bushels of corn; while on another set of plots the average increases produced by limestone were 4.8 bushels of wheat, 9.3 bushels of oats, and 12.0 bushels of corn. In this second series of experiments the legume crops (except the seed) are plowed under for soil improvement; but no seed was produced either on the cowpeas in 1910 or on the clover in 1911, and consequently the effect of the limestone on the legume crops was not determined in this system.

If we accept the average of the two series and compute the effect from these data for the four-year rotation, we find a return of $12.20 from an investment of $7.50 in limestone; and the limestone applied to the soil is sufficient to last for more than 10 years. These data strongly support those from the Vienna field in showing the positive value and need of limestone in the very beginning of improvement for these acid upland soils of southern Illinois.

The work at Raleigh has been carried on for only two years, and the organic manures thus far produced and returned to the soil are too meager to produce results from which trustworthy conclusions can be drawn concerning either the nitrogen secured or the phosphorus and potassium liberated; but that the addition of fine-ground raw rock phosphate in connec-

TABLE 6.—FERTILITY IN THE SOILS OF HARDIN COUNTY, ILLINOIS

Average pounds per acre in 4 million pounds of subsurface soil (about 6⅔ to 20 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone required
	Upland Timber Soils								
135	Yellow silt loam	9670	1390	1930	71340	19780	7650		8910
134	Yellow-gray silt loam	13600	1500	1820	64320	15000	8060		2780
864	Yellow fine sandy loam...	12920	1640	1960	67640	17560	7840		5000
	Swamp and Bottom-land Soils								
1323	Red-brown clay loam .	35120	3960	3180	86200	25240	9720	3220	
1331	Deep gray silt loam	10480	960	880	55280	11640	11400		2280
1361.1	Mixed fine sandy loam...	28460	2580	1220	56860	8960	9860	2000	
1380	River sand....	18960	760	1840	33640	10640	20080	30760	
	Terrace Soils								
1516	Gray clay	43920	4160	2080	77200	28200	23240		40
1530	Gray silt loam on tight clay	21400	2080	1800	88720	34480	13160		2800

TABLE 7.—FERTILITY IN THE SOILS OF HARDIN COUNTY, ILLINOIS

Average pounds per acre in 6 million pounds of subsoil (about 20 to 40 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone required
	Upland Timber Soils								
135	Yellow silt loam	8060	1310	2700	109070	30670	19580		10060
134	Yellow-gray silt loam.	10020	1620	2610	94530	25830	12330		13950
864	Yellow fine sandy loam ..	8400	1500	3240	107400	29580	13320		10080
	Swamp and Bottom-land Soils								
1323	Red-brown clay loam	35910	4080	4440	130800	36210	14610	4560	
1331	Deep gray silt loam	12300	1380	1440	86340	21600	17760		2520
1361.1	Mixed fine sandy loam ..	41550	3990	2370	78180	13590	17100	3000	
1380	River sand	24480	660	1740	47160	13080	24960	32880	
	Terrace Soils								
1516	Gray clay	33480	3000	2460	106200	43560	36180		60
1530	Gray silt loam on tight clay .	31200	3420	2880	132660	51120	19980		1500

tion with organic manures (farm manure, green manures or crop residues) will prove profitable on these undulating or gently rolling upland soils is very certain from the results already secured from other experiment fields. (See Soil Reports Nos. 1 and 2, and Circulars 116, 149, and 157.) On the other hand, the first step in the upbuilding of these soils is the liberal

use of limestone in connection with clover or other legume crops grown in rotation with corn and other grains; and when the legume crops or farm manures are available to plow under in significant amount then is the time to begin the application of phosphate, to be turned under in intimate contact with the decaying organic matter. Where used in this way on very similar land at the Ohio Agricultural Experiment Station, as an average of duplicate tests on three different series of plots during a period of fifteen years, every dollar invested in raw phosphate paid back $7.42, counting $7.50 per ton for the phosphate, 35 cents a bushel for corn, 70 cents for wheat, and $6.00 a ton for clover hay; while in a corresponding experiment every dollar invested in acid phosphate (at $15 per ton) paid back $3.69. (See Illinois Circulars 116, 127 and 130 for more details of these valuable Ohio experiments.)

No field experiments have been conducted on the less extensive soil types, but their composition is shown in Tables 2, 6 and 7, and their general characteristics and needs are discussed for each individual type in the following pages.

THE SUBSURFACE AND SUBSOIL

In Tables 6 and 7 are recorded the amounts of plant food per acre in the subsurface (6⅔ to 20 inches) and subsoil (20 to 40 inches), but it should be remembered that these supplies are of little value unless the top soil is kept rich, except that they serve as a source of renewal, even by very slight surface washing, for any element which they contain in great abundance, as is the case with potassium; and where much surface soil is removed by erosion, as on the rolling hill land, even the supply of phosphorus is renewed from the substrata in amounts which may equal or exceed the requirements of the crops that are grown where nitrogen is so commonly the limiting element.

Among the most important information contained in Tables 6 and 7 is that the upland soils are even more strongly acid in the subsurface and subsoil than in the surface stratum, thus emphasizing the importance of putting plenty of limestone in the surface soil to neutralize the acid moisture which rises from the lower strata by capillary action during the periods of partial drouth, which are also critical periods in the life of such plants as clover.

In the case of the less rolling upland (yellow-gray silt loam) where surface washing is not marked, the basic elements have been leached out and replaced with acid to such a depth that the subsoil is even more strongly acid than the subsurface, altho this is not the case with the yellow silt loam; and where very marked recent erosion has occurred, almost unleached subsoil containing limestone is sometimes exposed.

INDIVIDUAL SOIL TYPES

(a) UPLAND TIMBER SOILS

Yellow Silt Loam (135)

This is by far the most common type in the county, occupying 70.5 percent of the area, or 120 square miles. The soil was formed from material derived from glacial or alluvial formations, carried by the winds and deposited at all altitudes. The average depth of this loess or wind-blown material is not far from ten feet. The residue from the decay of the rocks has been so completely buried that it forms ordinarily no part of the soil. This residual material may be seen in some cuts as a reddish clay, frequently mixed with angular cherty or flinty pebbles. The topography of this type varies from rolling to very hilly and includes some land that should not be cultivated at all or that may be farmed only with the greatest care to avoid loss by erosion. Much of this type has been abandoned agriculturally already, and some of it should never have been cleared of its protecting forests. It frequently occurs that the northern slopes are abrupt, while those toward the south are more gradual and may be cultivated fairly well.

In the part of the county in the vicinity of Elizabethtown and Cave-in-Rock the rolling topography is due in part to the many sink-holes formed by the solution of the underlying limestone. These depressions vary in size from about 30 feet to several hundred feet in diameter and perhaps from 10 to 40 feet deep. They drain naturally into underground channels, but in many cases these drainage outlets have been stopped and sinkhole ponds result. About three miles northwest of Cave-in-Rock this obstructed drainage has resulted in the formation of a lake that covers an area of 100 acres or more, varying in extent with the time of year and the amount of rainfall. (The soil area shown as 1361.1 shows the limit of the lake when at its greatest size.)

The surface soil of the common hill land, 0 to 6⅔ inches, is a light brown to yellow silt loam varying with the amount of organic matter, which in turn is dependent to a large extent upon the amount of erosion. Usually the latter color prevails. The organic matter content is very low in this type, much too low for a fertile soil, about 1.1 per cent, as an average, in the surface soil, or only 11 tons per acre. From its yellow color this type is commonly called a clay soil; but it contains from 25 to 30 percent of fine sand, and much the larger part of the remaining 70 to 75 percent is silt, thus rendering it porous and mealy and easily worked; whereas true clay is plastic or gummy and very difficult to work. The surface soil is usually distinguished from the subsurface by a difference in color due to the still lower organic content of the subsurface soil.

The subsurface stratum is somewhat variable in thickness, depending upon the amount of erosion that has taken place, the average being about 8 or 9 inches. In some spots it is practically absent, while in others it is from 10 to 12 inches in thickness. It is a light yellow silt loam, mealy, porous, and pulverulent, the physical composition being a little finer than in the surface. The average organic matter content is .4 percent, or only 8 tons per acre for 4 million pounds of soil (6⅔ to 20 inches).

PLATE 3. YOUNG GROVE OF BLACK LOCUST TREES ON ROLLING HILL LAND IN JOHNSON COUNTY, ILLINOIS. (GROWN BY J. C. B. HEATON.)

The subsoil, extending from the subsurface stratum to a depth of 40 inches, is a yellow silt or slightly clayey silt. Gray blotches of unoxidized material often occur in the deeper subsoil. This stratum is more compact and not quite so porous as those above it, yet sufficiently pervious to allow water to pass thru it.

The variations of this type are produced chiefly by erosion. It represents varying degrees of fertility. In some places very little washing has occurred, in others the surface has been largely removed, while in others the subsoil may be exposed as unproductive yellow "clay points."

Of most importance in the management of this type is preventing much loss by washing. This process has gone on to such an extent that a large percentage of the type has been agriculturally abandoned, and so far not only has nothing been done to reclaim the abandoned land, but very little has been done to prevent further loss on land now under cultivation. Erosion occurs as sheet-washing and gullying. Ordinarily we do not think of sheet-washing as doing very much damage, but it is really the form that does the greatest amount of injury. Gullying results in the absolute ruin of small areas, but sheet washing reduces the productive capacity of large areas to such a point that not only profitable crops cannot be grown, but even the

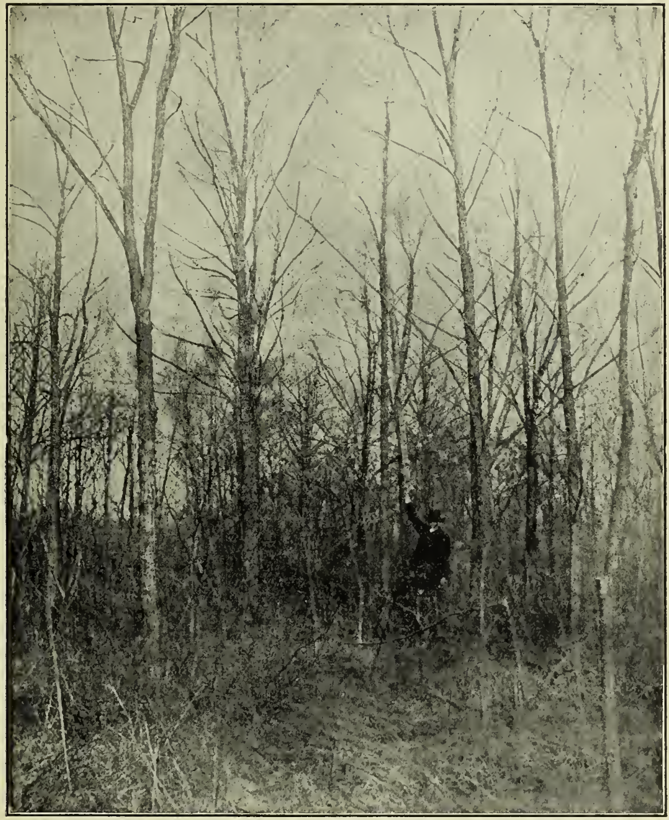


PLATE 4. GROVE OF LOCUST TREES ABOUT TWENTY-FIVE YEARS OLD ON ROLLING HILL LAND IN JOHNSON COUNTY, ILLINOIS. (GROWN BY J. C. B. HEATON.)

growth of crops large enough to pay for the raising becomes impossible. Every means should be taken to prevent this loss.

Steep gullied slopes probably never can be reclaimed with profit for cropping purposes at the present average prices for labor and farm produce. They were originally forested and these forests should never have been entirely removed. It was the only thing that made these lands valuable in the first place, and to make them of any future value they should be reforested. This has been done in a few cases with excellent success. The accompanying illustrations show such results. The black locust can be used most successfully for this purpose as it is largely independent of the supply

of nitrogenous organic matter in the soil. Where not in forest the steep land should be kept in pasture as much as possible, and if plowed should be cropped for only one or two years and then reseeded to pasture. Live stock is indispensable to farming on this type of soil.

Sheet washing on the moderate slopes may be prevented to a great extent by the following methods:

(1) By increasing the organic matter content, thus rendering the soil more porous, and binding the soil particles together. This can be done by adding farm manure, plowing under stubble, straw, cornstalks, and legume crops, such as clover and cowpeas.

(2) By deep plowing to increase the absorption of water and diminish the run-off. Ten inches of loose soil will readily absorb 2 inches of rainfall without run-off. Plowing should be done seven to ten inches deep.

(3) By contour plowing. Plowing in this state is often done up and down the hill, producing dead furrows that furnish excellent beginnings for gullies. Even the little depressions between furrows will aid washing. On land subject to serious washing, plowing should always be done across the slope on the contour, so that water will stand in the furrow without running in either direction. Every furrow will act as an obstruction to the movement of water down the slope, thus diminishing the velocity of the water, facilitating absorption, and diminishing the amount of run-off and the power of the water to do washing.

(4) By the use of cover crops to hold the soil during the winter and spring. Rye is a fairly good cover crop to sow in the corn during the late summer or early fall. Wheat, especially when seeded late, is a poor crop to grow on rolling land because it does not usually make sufficient growth to afford a good protection to the soil during winter. Of course both rye and wheat invite the development of chinch bugs. A mixture of winter vetch, and clover, with a few cowpeas, seeded at the time of the last cultivation of the corn, gives results in favorable seasons.

TABLE 8.—CROP YIELDS PER ACRE FROM RECLAIMED ABANDONED HILL LAND: VIENNA EXPERIMENT FIELD

Year	Field 1	Field 2	Field 3	Field 4
1906	Corn 20.4 bu.	Cowpeas turned		
1907	Cowpeas turned	Wheat 9 6 bu.	Clover 1.00 ton	Corn 24.4 bu.
1908	Wheat 7.9 bu.	Clover .77 ton	Corn 33.5 bu.	Cowpeas turned
1909	Clover .60 ton*	Corn 37.8 bu.	Cowpeas turned	Wheat 8.8 bu.
1910	Corn 38.6 bu.	Cowpeas turned	Wheat 15.6 bu.	Clover 1.53 tons
1911		Wheat 17 6 bu.		Corn 32.8 bu.

Average Yields of Crops Grown

	Corn	Wheat	Clover
1906-1908	25 1 bu.	8.8 bu.	.89 ton
1909-1911	36.4 bu.	14.0 bu.	1.07 tons

*The yield of clover for 1909 is estimated, the weights not having been taken because of a misunderstanding.

Experiments in methods of preventing soil erosion are being carried on in Johnson county near Vienna on abandoned land purchased in 1906 by the University of Illinois. In addition to the methods above described, two tons per acre of ground limestone are applied every four years. The

results show that this land may be reclaimed and made to produce fair crops, as is shown in Table 8.

These results show that fairly good crops may be grown upon this abandoned land if proper care is taken to reduce washing, and if use is made of ground limestone and a good crop rotation. The results also indicate that the crop yields tend to increase under this system. (See also Tables 3, 4 and 5.)

Alfalfa may well be one of the crops grown in this type of soil. Note the suggested rotation and directions under *Yellow-Gray Silt Loam* and *Yellow Fine Sandy Loam.*

Yellow-Gray Silt Loam (134)

This type occurs only in limited, somewhat isolated areas over the county, usually surrounded by yellow silt loam (135). The type covers 10.5 square miles, or 6.17 percent of the area of the county. It comprises the less rolling areas of the upland and furnishes some good agricultural land. The topography varies from slightly undulating to rolling. All of this land may be cultivated but in some places where it grades toward the yellow silt loam care must be taken to prevent washing. Its origin is the same as the yellow silt loam (135).

The surface soil, 0 to 6⅔ inches, is a yellow to yellowish gray silt loam, porous, mealy, and pulverulent. Its good physical condition is due to the considerable percentage of fine sand that it contains. The organic matter content is low, the average being 1.35 percent—but slightly higher than the yellow silt loam.

The subsurface stratum, varying from about 8 to 12 inches in thickness, is a yellow to grayish yellow silt loam distinguished from the surface soil by its lighter color. Its physical composition is very much like the surface except that there is less organic matter, only .56 percent.

The subsoil from the subsurface to a depth of 40 inches is a compact yellow or grayish yellow silt or clayey silt, plastic when wet. Concretions of iron are found in the subsurface and subsoil in the more nearly level areas.

While the type is one of the best in the county, the supply of organic matter should be increased to keep the soil in good physical condition and thus prevent washing.

At least 2 tons per acre of ground limestone should be applied, and 4 or 5 tons would be even more profitable for the initial application, after which about 2 tons every four or five years will be sufficient to keep the soil sweet. Legume crops should be grown in a good rotation, such, for example, as corn, cowpeas, wheat, and clover, on four fields, with alfalfa on a fifth field. After five years the alfalfa field may be broken up and used for the four-year rotation, one of the four fields being seeded to alfalfa for another five-year period. (See also Yellow Fine Sandy Loam, page 18.)

The organic matter and nitrogen should be increased either by using all crops except the wheat for feed and bedding, saving and retaining the manure produced, or by selling only grain or seed and some alfalfa hay and plowing under all other crops and residues.

About 1,000 pounds per acre of very finely ground rock phosphate should be plowed under with the organic matter every four or five years, and the initial application may well be at least 1 ton per acre. Temporarily some use may well be made of steamed bone meal, as by drilling about 200 pounds

per acre when seeding wheat on land where no adequate provision has been made for the decaying organic matter required to liberate phosphorus from the raw phosphate used in the more profitable permanent systems of soil improvement.

In composition this type of soil resembles that of the gray silt loam prairie (330) described in Soil Report No. 1, and the reader's attention is called to Tables 3, 6 and 7 in that report, showing the composition of the prairie soil and the results obtained from field experiments conducted in that soil at DuBois and Fairfield. The Raleigh experiment field, referred to in the preceding pages, is located in the yellow-gray silt loam, and, tho recently established, is already beginning to show valuable results from proper methods of soil improvement.

Yellow Fine Sandy Loam (864)

Only a small area of this type is found in the county, amounting to 294 acres. It occurs on the point extending southward in a bend of the Ohio river, thus furnishing a place of deposit for the material picked up by the wind sweeping over the bottom land when exposed at times of low water.

The area is small and very rolling so that very little is under cultivation. In some counties along the Mississippi river this type occurs in very extensive areas. Where cultivated it should be protected from excessive surface washing, and liberal use should be made of ground limestone and organic matter. The soil is especially adapted to the growing of alfalfa when well inoculated and sweetened with about 5 tons per acre of limestone; but, in order to give the alfalfa a good start, a moderate application of farm manure or 500 to 1000 pounds per acre of acid phosphate (or still better, both manure and acid phosphate) should be plowed under. After the alfalfa is well started it roots very deeply and becomes almost independent of the top soil, except with respect to limestone.

Stony Loam (198)

This type occurs on the slopes of hills and ridges where erosion has removed most of the loess and residual material, to a large extent leaving a mixture of these and stones to constitute the soil. The stones vary from a few inches to several feet in diameter. It comprises 17.05 square miles, or 10 percent of the entire area. It is of little agricultural value, its only use, aside from growing of forests, being for pasture.

Rock Outcrop (199)

This can hardly be considered a type of soil but may have some value as a source of limestone for use on acid soils.

The outcrop occurs frequently as perpendicular ledges, and the horizontal width is often somewhat exaggerated in order to show the boundary lines on the soil map.

(b) SWAMP AND BOTTOM-LAND SOILS

Red-Brown Clay Loam (1323)

This type comprises the greater amount of the bottom land along the Ohio river, the total area being 3.16 square miles or 1.86 percent of the area of the county. Two large areas occur, one in the southwest and the other

in the southeast. A few small areas occur at the mouths of some of the small creeks that flow into the Ohio. This type is formed by deposit from the flood waters of the Ohio river and has been found in all of the counties surveyed that border on that river.

The topography varies from almost flat to gently undulating, the undulations being due to the narrow but elevated ridges and depressions formed by currents during overflow. The drainage is not always good, there being many low, wet places in which the crop may be badly damaged.

The surface soil, 0 to 6⅔ inches, is a yellow to reddish brown clay loam, plastic, but granular under proper conditions. Like all clays and clay loams, it will become hard and intractable if worked when wet, due to puddling or the breaking down of the granules. This will be restored by the moistening and drying produced by showers or by freezing and thawing.

The amount of organic matter varies from 2¼ to 3½ percent, with an average of about 2¾ percent. The physical composition varies somewhat, the heavier phase being near the bluff and on the lower ground, and the lighter or more sandy near the river.

The subsurface, 6⅔ to 20 inches, is not distinctly separated from either the surface or subsoil. The color gradually becomes lighter with depth, due to the smaller amount of organic matter, which is 1.5 percent in this stratum.

The subsoil, 20 to 40 inches, is a yellowish brown clay loam, tough and plastic, yet pervious to water. It varies slightly with the topography, the lower areas having a heavier subsoil.

This soil is more difficult to manage than a lighter soil, owing to the danger of puddling if worked when too wet and to its cloddy character when dry. This type cracks rather badly owing to the property of shrinkage which clay possesses to such a degree. Corn is the chief crop, but where protected from overflow other crops can be grown. The soil is rich in mineral plant food, but legumes should be grown in the rotation where the land does not overflow.

Deep Gray Silt Loam (1331)

This type is found in some of the wider bottoms of the small streams, mostly near their mouths. It is formed from material washed from the hills. It seems to be an older deposit than the mixed sandy loam (1361.1) and is occasionally a little higher bottom land. Since its deposition the iron has been deoxidized, and as a result the color has been changed from a yellow or brownish to a gray or light drab. The topography is flat to gently undulating. The extent of this type in the county is 768 acres, constituting only .65 percent of the total area of the county.

The surface, 0 to 6⅔ inches, is a gray silt loam varying to a yellowish gray silt loam or fine sandy loam. Iron concretions are usually found upon the surface and mixed with the surface and subsurface strata. All of this type contains considerable fine sand, giving it an almost ideal physical composition. It is very low in oragnic matter, having only about 1 percent.

The subsurface, 6⅔ to 20 inches, is a gray silt loam, friable, pulverulent, but compact and not very pervious, especially upon the higher and apparently older areas.

The subsoil is mostly a gray silt, but varies from this to a gray silty clay, compact, tough and almost impervious, resembling the subsoil of the gray silt loam on tight clay on the more elevated parts of the bottom land

The type is drained poorly as a rule, and better drainage with the addition of organic matter are the first requirements for improvement, altho it will be necessary to add limestone to get the organic matter by the growing of legumes, because of the acidity of the soil and subsoil. Where protected from overflow phosphorus should also be applied in systems of permanent improvement.

Mixed Fine Sandy Loam (1361.1)

This type is found along the small stream of the county as bottom land, varying in width from a few rods to a half mile, altho in these wider places the soil may grade toward the deep gray silt loam. The material forming this type has been rather recently washed from the surrounding hills, the finer particles being carried into the Ohio river, while the coarser are deposited in these bottoms.

The topography is flat to gently undulating, the undulations being due to the old system channels and those produced during floods. Natural drainage is usually good. In some places the type is underlain by gravel.

The total area of the type is 8074 acres or 7.4 percent of the entire area of the county.

The surface, subsurface and subsoil are practically the same, the chief difference being in the amount of organic matter in some places, altho this does not vary as much as might be supposed. The amount varies from 1 to 1½ percent in the surface soil. This is one of the best types in the county, producing fair crops of corn, wheat and cowpeas.

As a rule this soil is not acid, more or less of the material being almost unweathered, having been recently washed out of deep gullies.

Because of the porous character of the soil and subsoil, and the consequent deep-feeding range afforded to plant roots, and also because of the liability to overflow, it is very doubtful if any purchased materials should be applied to this kind of land; but legumes should be grown in rotation where conditions permit.

River Sand (1380)

This type covers about 130 acres along the Ohio river in the southward extension southwest of Rosiclare and is a deposit formed by water and reworked to some extent by wind. The sand is largely derived from a sand bar beside this area on the north side of the river, this sand bar being exposed during low water.

There is very little difference between the different strata of sand except that occasional layers of silt or clay from 2 to 4 inches thick are found in the subsoil. These have been deposited during overflow from the Ohio river.

The sand is exceedingly poor in organic matter and nitrogen, altho the ratio between the organic carbon and nitrogen indicates that the small amount of organic matter present is in moderately fresh condition, as might be expected from the formation and age of this river sand. Where it is cultivated, legume crops should be grown in the rotation if practicable. Considering its composition and very porous character, no applications can be advised except nitrogenous organic matter, best secured as a rule by legume crops.

(c) TERRACE SOILS

Gray Clay (1516)

This type comprises about 196 acres, mostly in the northeast part of the county. There are two small areas in the southwestern part along small streams. This with the type described below (gray silt loam on tight clay) represents an old fill, or terrace deposit, caused by the silting up of the Ohio and its tributaries and later cutting down thru them by stream erosion to the level of the present bottom land. The topography is flat, with the exception of a few small draws that have been made by streams.

The surface, 0 to 6⅔ inches, is a gray to dark drab clay, with iron stains, very plastic, and possessing the property of shrinkage to a marked degree. This stratum contains about 3 percent of organic matter.

The subsurface and subsoil are composed of a gray, sticky, plastic clay with blotches of yellow.

The soil is very difficult to work; it is easily puddled when too wet, and when dry is very cloddy. It granulates under proper conditions of moisture. Its chief value is for permanent pasture or hay, but even for these purposes it is not a good soil; and because of the physical difficulties it is doubtful if any method of enrichment would be profitable; but if so it would be with limestone, organic matter and possibly phosphorus.

Gray Silt Loam on Tight Clay (1530)

This type is like the gray clay (1516) in that it is part of an old clay terrace, but in this case a deposit of silt from 7 to 12 inches deep was made upon the tight clay layer. It occurs in the northeastern part of the county along Harris creek and Saline river and along three small creeks in the vicinity of Elizabethtown.

The total area is 755 acres. It is very flat and poorly drained. While it is a distinct terrace yet part of it overflows during extremely high water. Tile would be of little use because of the almost impervious subsoil.

The surface soil, 0 to 6⅔ inches, is a gray silt loam having about 2 percent of organic matter, sometimes with a yellow tinge due to iron.. It varies from a loose pulverulent silt loam to a somewhat sticky clayey silt loam.

The subsurface stratum is sometimes represented by a layer of gray silt loam extending to a depth of 12 inches, but often the clay subsoil begins at a depth of 7 inches and continues without any material change to a depth of 40 inches. The subsoil is a gray or yellowish clay, tough, plastic and nearly impervious.

The type has a very low value for agricultural purposes. It produces but little corn or wheat, and grass makes but poor growth. Much of it is still covered with timber, and probably this is the best crop that can be grown upon it. If put under cultivation and protected from overflow, it should be treated with ground limestone, and legume crops should be grown in the rotation; and with long continued cropping phosphorus would need to be supplied, altho in its virgin condition it is fairly rich in that element, as shown in Table 2.

APPENDIX

A study of the soil map and the tabular statements concerning crop requirements, the plant food content of the different soil types, and the actual results secured from definite field trials with different methods or systems of soil improvement, and a careful study of the discussion of general principles and of the descriptions of individual soil types will furnish the most necessary and useful information for the practical improvement and permanent preservation of the productive power of every kind of soil on every farm in the county.

More complete information concerning the most extensive and important soil types in the great soil areas in all parts of Illinois is contained in Bulletin 123, "The Fertility of Illinois Soils," which contains a colored general survey soil map of the entire state.

Other publications of general interest are:

Bulletin No. 76, "Alfalfa on Illinois Soils"
Bulletin No. 94, "Nitrogen Bacteria and Legumes"
Bulletin No. 99, "Soil Treatment for the Lower Illinois Glaciation"
Bulletin No. 115, "Soil Improvement for the Worn Hill Lands of Illinois"
Bulletin No. 125, "Thirty Years of Crop Rotation on the Common Prairie Lands of Illinois"
Circular No. 110, "Ground Limestone for Acid Soils"
Circular No. 127, "Shall we use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils?"
Circular No. 129, "The Use of Commercial Fertilizers"
Circular No. 149, "Some Results of Scientific Soil Treatment" and "Methods and Results of Ten Years' Soil Investigation in Illinois"

NOTE.—Information as to where to obtain limestone, phosphate, bone meal, and potassium salts, methods of application, etc., will also be found in Circulars 110 and 149.

SOIL SURVEY METHODS

The detail soil survey of a county consists essentially of indicating on a map the location and extent of the different soil types; and, since the value of the survey depends upon its accuracy, every reasonable means is employed to make it trustworthy. To accomplish this object three things are essential: first, careful, well-trained men to do the work; second, an accurate base map upon which to show the results of their work: and, third, the means necessary to enable the men to place the soil-type boundaries, streams, etc., accurately upon the map.

The men selected for the work must be able to keep their location exactly and to recognize the different soil types, with their principal variations and limits, and they must show these upon the maps correctly. A definite system is employed in checking up this work. As an illustration, one soil expert will survey and map a strip 80 rods or 160 rods wide and any convenient length, while his associate will work independently on another strip adjoining this area, and, if the work is correctly done, the soil type boundaries will match up on the line between the two strips.

An accurate base map for field use is absolutely necessary for soil mapping. The base maps are made on a scale of one inch to the mile. The official data of the original or subsequent land survey are used as a basis in the construction of these maps, while the most trustworthy county map available is used in locating temporarily the streams, roads, and railroads. Since the best of these published maps have some inaccuracies, the location of every road, stream, and railroad must be verified by the soil surveyors, and cor-

rected if wrongly located. In order to make these verifications and corrections, each survey party is provided with an odometer for measuring distances, and a plane table for determining the directions of roads, railroads, etc.

Each surveyor is provided with a base map of the proper scale, which is carried with him in the field; and the soil-type boundaries, additional streams, and necessary corrections are placed with proper locations upon the map while the mapper is on the area. Each section, or square mile, is divided into 40-acre plots on the map and the surveyor must inspect every ten acres and determine the type or types of soil composing it. The different types are indicated on the map by different colors, pencils being carried in the field for this purpose.

A small augur 40 inches long forms for each man an invaluable tool with which he can quickly secure samples of the different strata for inspection. An extension for making the augur 80 inches long is taken by each party, so that any peculiarity of the deeper subsoil layers may be studied. Each man carries a compass to aid in keeping directions. Distances along roads are measured by an odometer attached to the axle of the vehicle, while distances in the field off the roads are determined by pacing, an art in which the men become expert by practice. The soil boundaries can thus be located with as high a degree of accuracy as can be indicated by pencil on the scale of one inch to the mile.

SOIL CHARACTERISTICS

The unit in the soil survey is the soil type, and each type possesses more or less definite characteristics. The line of separation between adjoining types is usually distinct, but sometimes one type will grade into another so gradually that it is very difficult to draw the line between them. In such exceptional cases, some slight variation in the location of soil-type boundaries is unavoidable.

Several factors must be taken into account in establishing soil types. These are (1) the geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial, or cumulose; (2) the topography, or lay of the land; (3) native vegetation, as forest or prairie grasses; (4) the structure, or the depth and character of the surface, subsurface, and subsoil; (5) the physical or mechanical composition of the different strata composing the soil, as the percentages of gravel, sand, silt, clay, and organic matter which they contain; (6) the texture, or porosity, granulation, friability, plasticity, etc.; (7) the color of the strata; (8) the natural drainage; (9) agricultural value, based upon its natural productiveness; (10) the ultimate chemical composition and reaction.

The common soil constituents are indicated in the following outline:

CONSTITUENTS OF SOILS

Soil Constituents	Organic Matter	Comprising undecomposed and partially decayed vegetable material	
	Inorganic Matter	Clay	.001 mm.* and less
		Silt	.001 mm. to .03 mm.
		Sand	.03 mm. to 1. mm.
		Gravel	1. mm. to 32 mm.
		Stones	32. mm. and over

*25 millimeters equal 1 inch.

Further discussion of these constituents is given in Circular 82.

GROUPS OF SOIL TYPES

The following gives the different general groups of soils:

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or silt.

Peaty loams—15 to 35 percent of organic matter mixed with much sand and silt and a little clay.

Mucks—15 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 25 percent of clay, usually mixed with much silt.

Clay loams—Soils with from 15 to 25 percent of clay, usually mixed with much silt and some sand.

Silt loams—Soils with more than 50 percent of silt and less than 15 percent of clay, mixed with some sand.

Loams—Soils with from 30 to 50 percent of sand mixed with much silt and a little clay.

Sandy loams—Soils with from 50 to 75 percent of sand.

Fine sandy loams—Soils with from 50 to 75 percent of fine sand mixed with much silt and little clay.

Sands—Soils with more than 75 percent of sand.

Gravelly loams—Soils with 15 to 50 percent gravel with much sand and some silt.

Gravels—Soils with more than 50 percent of gravel.

Stony loams—Soils containing a considerable number of stones over one inch in diameter.

Rock outcrop—Usually ledges of rock having no agricultural value.

More or less organic matter is found in nearly all of the above classes.

SUPPLY AND LIBERATION OF PLANT FOOD

The productive capacity of land in humid sections depends almost wholly upon the power of the soil to feed the crop; and this, in turn, depends both upon the stock of plant food contained in the soil and upon the rate at which this is liberated, or rendered soluble and available for use in plant growth. Protection from weeds, insects, and fungous diseases, tho exceedingly important, is not a positive but a negative factor in crop production.

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but the rate of liberation is governed by many factors, some of which may be controlled by the farmer, while others are largely beyond his control. Chief among the important controllable factors which influence the liberation of plant food are limestone and decaying organic matter, which may be added to the soil by direct application of ground limestone and farm manure. Organic matter may also be supplied by green-manure crops and crop residues, such as clover, cowpeas, straw, and cornstalks. The rate of decay of organic matter depends largely upon its age and origin, and it may be hastened by tillage. The chemical analysis shows correctly the total organic carbon, which represents, as a rule, but little more than half the organic matter; so that 20,000 pounds of organic carbon in the plowed soil of an acre correspond to nearly 20 tons of organic matter. But this organic matter consists largely of the

old organic residues that have accumulated during the past centuries because they were resistant to decay, and 2 tons of clover or cowpeas plowed under may have greater power to liberate plant food than the 20 tons of old inactive organic matter. The recent history of the individual farm or field must be depended upon for information concerning recent additions of active organic matter, whether in applications of farm manure, in legume crops, or in grass-root sods of old pastures.

Probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that with the normal rainfall of Illinois the productive power of the land depends primarily upon the stock of plant food contained in the soil and upon the rate at which it is liberated, just as the success of the merchant depends primarily upon his stock of goods and the rapidity of sales. In both cases the stock of any commodity must be increased or renewed whenever the supply of such commodity becomes so depleted as to limit the success of the business, whether on the farm or in the store.

As the organic matter decays, certain decomposition products are formed, including much carbonic acid, some nitric acid, and various organic acids, and these have power to act upon the soil and dissolve the essential mineral plant foods, thus furnishing soluble phosphates, nitrates, and other salts of potassium, magnesium, calcium, etc., for the use of the growing crop.

As already explained, fresh organic matter decomposes much more rapidly than the old humus, which represents the organic residues most resistant to decay and which consequently have accumulated in the soil during the past centuries. The decay of this old humus can be hastened both by tillage, which maintains a porous condition and thus permits the oxygen of the air to enter the soil more freely and to effect the more rapid oxidation of the organic matter, and also by incorporating with the old resistant residues some fresh organic matter, such as farm manure, clover roots, etc., which decay rapidly and which thus furnish or liberate organic matter and inorganic food for bacteria, which, under such favorable conditions appear to have power to attack and decompose the old humus. It is probably for this reason that peat, a very inactive and inefficient fertilizer when used by itself, becomes much more effective when incorporated with fresh farm manure; so that, when used together, two tons of the mixture may be worth as much as two tons of manure, but if applied separately, the peat has little value. Bacterial action is also promoted by the presence of limestone.

The condition of the organic matter of the soil is indicated more or less definitely by the ratio of carbon to nitrogen. As an average, the fresh organic matter incorporated with soils contains about twenty times as much carbon as nitrogen, but the carbohydrates ferment and decompose much more rapidly than the nitrogenous matter; and the old resistant organic residues, such as are found in normal subsoils, commonly contain only five or six times as much carbon as nitrogen. Soils of normal physical composition, such as loam, clay loam, silt loam, and fine sandy loam, when in good productive condition, contain about twelve to fourteen times as much carbon as nitrogen in the surface soil; while in old worn soils that are greatly in need of fresh

active organic manures, the ratio is narrower, sometimes falling below ten of carbon to one of nitrogen. (Except in newly made alluvial soils, the ratio is usually narrower in the subsurface and subsoil than in the surface stratum.)

It should be kept in mind that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all agricultural plants, only one (hydrogen) from water, and seven from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes), in case the amount liberated from the soil is insufficient; but even these plants (which include only the clovers, peas, beans, and vetches among our common agricultural plants) secure only from the soil six elements (phosphorus, potassium, magnesium, calcium, iron and sulfur), and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Plants are made of plant-food elements in just the same sense that a building is made of wood and iron, brick, stone, and mortar. Without materials, nothing material can be made. The normal temperature, sunshine, rainfall, and length of season in central Illinois are sufficient to produce 50 bushels of wheat per acre, 100 bushels of corn, 100 bushels of oats, and 4 tons of clover hay; and, where the land is properly drained and properly tilled, such crops would frequently be secured *if the plant foods were present in sufficient amounts and liberated at a sufficiently rapid rate to meet the absolute needs of the crops.*

CROP REQUIREMENTS

The accompanying table shows the requirements of such crops for the five most important plant food elements which the soil must furnish. (Iron and sulfur are supplied normally in sufficient abundance compared with the amounts needed by plants, so that they are not known ever to limit the yield of general farm crops grown under normal conditions).

TABLE A.—PLANT FOOD IN WHEAT, CORN, OATS, AND CLOVER

Produce		Nitrogen, pounds	Phosphorus, pounds	Potassium, pounds	Magnesium, pounds	Calcium, pounds
Kind	Amount					
Wheat, grain	50 bu.	71	12	13	4	1
Wheat straw	2½ tons	25	4	45	4	10
Corn, grain	100 bu.	100	17	19	7	1
Corn stover	3 tons	48	6	52	10	21
Corn cobs	½ ton	2	..	2	..	..
Oats, grain	100 bu.	66	11	16	4	2
Oat straw	2½ tons	31	5	52	7	15
Clover seed	4 bu	7	2	3	1	1
Clover hay	4 tons	160	20	120	31	117
Total in grain and seed		244*	42	51	16	4
Total in four crops		510*	77	322	68	168

*These amounts include the nitrogen contained in the clover seed or hay, which however may be secured from the air.

To be sure, these are large yields, but shall we try to make possible the production of yields only half or a quarter as large as these, or shall we set as our ideal this higher mark, and then approach is as nearly as possible with profit? Among the four crops, corn is the largest, with a total yield of more than six tons per acre; and yet the 100-bushel crop of corn is often produced on rich pieces of land in good seasons. In very practical and profitable systems of farming, the Illinois Experiment Station has produced, as an average of the six years 1905 to 1910, a yield of 87 bushels of corn per acre in grain farming (with limestone and phosphorus applied, and with crop residues and legume crops turned under), and 90 bushels per acre in live-stock farming (with limestone, phosphorus, and manure).

On the Fairfield experiment field in Wayne county, on the common prairie land of southern Illinois, yields have been obtained in favorable seasons as high as 90 bushels per acre of corn, and 3½ tons of air-dry clover hay.

The importance of maintaining a rich surface soil cannot be too strongly emphasized. It is well illustrated by data from the Rothamsted Experiment Station, the oldest in the world. Thus on Broadbalk field, where wheat has been grown since 1844, the average yields for the ten years 1892 to 1901 were 12.3 bushels per acre on Plot 3 (unfertilized) and 31.8 bushels on Plot 7 (well fertilized), but the amounts of both nitrogen and phosphorus in the subsoil (9 to 27 inches) were distinctly greater in Plot 3 than in Plot 7, thus showing that the higher yields from Plot 7 were due to the fact that the plowed soil had been enriched. In 1893 Plot 7 contained per acre in the surface soil (0 to 9 inches) about 600 pounds more nitrogen and 900 pounds more phosphorus than Plot 3. Even a rich subsoil has little value if it lies beneath a worn-out surface.

METHODS OF LIBERATING PLANT FOOD

Limestone and decaying organic matter are the principal materials the farmer can utilize most profitably to bring about the liberation of plant food.

The limestone corrects the acidity of the soil and thus encourages the devolopment not only of the nitrogen-gathering bacteria which live in the nodules on the roots of clover, cowpeas, and other legumes, but also the nitrifying bacteria which have power to transform the insoluble and unavailable organic nitrogen into soluble and available nitrate nitrogen.

At the same time the products of this decomposition have power to dissolve the minerals contained in the soil, such as potassium and magnesium, and also to dissolve the insoluble phosphate and limestone which may be applied in low-priced forms.

Tillage, or cultivation, also hastens the liberation of plant food by permitting the air to enter the soil and burn out the organic matter; but it should never be forgotten that tillage is wholly destructive, that it adds nothing whatever to the soil, but always leaves the soil poorer. Tillage should be practiced so far as is necessary to prepare a suitable seed-bed for root development and also for the purpose of killing weeds, but more than this is unnecessary and unprofitable in seasons of normal rainfall; and it is much better actually to enrich the soil by proper applications or additions, including limestone and organic matter (both of which have power to improve the physical condition as well as to liberate plant food) than merely to hasten soil depletion by means of excessive cultivation.

PERMANENT SOIL IMPROVEMENT

The best and most profitable methods for the permanent improvement of the common soils of Illinois are as follows:

(1) If the soil is acid apply at least two tons per acre of ground limestone, preferably at times magnesian limestone ($CaCO_3MgCO_3$), which contains both calcium and magnesium, and has slightly greater power to correct soil acidity, ton for ton, than the ordinary calcium limestone ($CaCO_3$); and continue to apply about two tons per acre of ground limestone every four or five years. On strongly acid soils, or in preparing the land for alfalfa, five tons per acre of ground limestone may well be used for the first application.

(2) Adopt a good rotation of crops, including a liberal use of legumes, and increase the organic matter of the soil either by plowing under the legume crops and other crop residues (straw and corn stalks) or by using for feed and bedding practically all of the crops raised and returning the manure to the land with the least possible loss. No one can say in advance what will prove to be the best rotation of crops, because of variation in farms and farmers, and in prices for produce, but the following are suggested to serve as models or outlines:

First year, corn (with some winter legume, such as red clover, alsike, sweet clover, or alfalfa, or a mixture, seeded on part of the field at the last cultivation).

Second year, oats or barley or wheat (fall or spring) on one part and cowpeas or soybeans where the winter catch crop is plowed down late in the spring.

Third year, wheat or oats (with clover or clover and grass).

Fourth year, clover or clover and grass.

Fifth year, wheat and clover or grass and clover.

Sixth year, clover or clover and grass.

Of course there should be as many fields as there are years in the rotation. In grain farming, with wheat grown the third and fifth years, most of the coarse products should be returned to the soil, and the clover may be clipped and left on the land (only the clover seed being sold the fourth and sixth years); or, in live-stock farming, the field may be used three years for timothy and clover pasture and meadow if desired. The system may be reduced to a five-year rotation by cutting out either the second or the sixth year; and to a four-year system by omitting the fifth and sixth years.

With two years of corn, followed by oats with clover-seeding the third year, and by clover the fourth year, all produce can be used for feed and bedding if other land is available for permanent pasture. Alfalfa may be grown on a fifth field for four or eight years, which is to be alternated with one of the four; or the alfalfa may be moved every five years, and thus rotated over all five fields every twenty-five years.

Other four-year rotations more suitable for grain farming are:

Wheat (and clover), corn, oats, and clover, or corn (and clover), cowpeas, wheat, and clover. (Alfalfa may be grown on a fifth field and rotated every five years, the hay being sold.)

Good three-year rotations are:

Corn, oats, and clover; corn, wheat, and clover; or wheat (and clover), corn (and clover), and cowpeas, in which two cover crops and one regular crop of legumes are grown in three years.

A five-year rotation of (1) corn (and clover), (2) cowpeas, (3) wheat, (4) clover, (5) wheat (and clover), allows legumes to be seeded four times, and alfalfa may be grown on a sixth field for five or six years in the com-

bination rotation, alternating between two fields every five years, or rotating over all fields if moved every six years.

To avoid clover sickness it may sometimes be necessary to substitute red clover or alsike for the other in about every third rotation, and at the same time to discontinue their use in the cover-crop mixture. If the corn crop is not too rank, cowpeas or soybeans may also be used as a cover-crop (seeded at the last cultivation) in the southern part of the state and, if necessary to avoid disease, these may well alternate in successive rotations.

For easy figuring it may well be kept in mind that the following amounts of nitrogen are required for the produce named:

1 bushel of oats (grain and straw) requires 1 pound of nitrogen.
1 bushel of corn (grain and stalks) requires 1½ pounds of nitrogen.
1 bushel of wheat (grain and straw) requires 2 pounds of nitrogen.
1 ton of timothy requires 24 pounds of nitrogen.
1 ton of clover contains 40 pounds of nitrogen.
1 ton of cowpeas contains 43 pounds of nitrogen.
1 ton of average manure contains 10 pounds of nitrogen.

The roots of clover contain about half as much nitrogen as the tops, and the roots of cowpeas contain about one-tenth as much as the tops.

Soils of moderate productive power will furnish as much nitrogen to clover (and two or three times as much to cowpeas) as will be left in the roots and stubble. For grain crops, as wheat, corn, and oats, about two-thirds of the nitrogen is contained in the grain and one-third in the straw or stalks. (See also discussion of "The Potassium Problem," on pages below.)

(3) On all lands deficient in phosphorus (except on those susceptible to serious erosion by surface washing or gullying) apply that element in considerably larger amounts than are required to meet the actual needs of the crops desired to be produced. The abundant information thus far secured shows positively that fine-ground natural rock phosphate can be used successfully and very profitably, and clearly indicates that this material will be the most economical form of phosphorus to use in all ordinary systems of permanent, profitable soil improvement. The first application may well be one ton per acre, and subsequently about one-half ton per acre every four or five years should be applied, at least until the phosphorus content of the plowed soil reaches 2,000 pounds per acre, which may require a total application of from three to five or six tons per acre of raw phosphate containing 12½ percent of the element phosphorus.

Steamed bone meal and even acid phosphate may be used in emergencies, but it should always be kept in mind that phosphorus delivered in Illinois costs about 3 cents a pound in raw phosphate (direct from the mine in carload lots), but 10 cents a pound in steamed bone meal, and about 12 cents a pound in acid phosphate, both of which cost too much per ton to permit their common purchase by farmers in carload lots, which is not the case with limestone or raw phosphate.

Phosphorus once applied to the soil remains in it until removed in crops, unless carried away mechanically by soil erosion. (The loss by leaching is only about 1½ pounds per acre per annum, so that more than 150 years would be required to leach away the phosphorus applied in one ton of raw phosphate.)

The phosphate and limestone may be applied at any time during the rotation, but a good method is to apply the limestone after plowing and work it into the surface soil in preparing the seed bed for wheat, oats, rye,

or barley, where clover is to be seeded; while phosphate is best plowed under with farm manure, clover, or other green manures, which serve to liberate the phosphorus.

(4) Until the supply of decaying organic matter has been made adequate, on the poorer types of upland timber and gray prairie soils some temporary benefit may be derived from the use of a soluble salt or mixture of salts, such as kainit, which contains both potassium and magnesium in soluble form and also some common salt (sodium chlorid). About 600 pounds per acre of kainit applied and turned under with the raw phosphate will help to dissolve the phosphorus as well as to furnish available potassium and magnesium, and for a few years such use of kainit will no doubt be profitable on lands deficient in organic matter, but the evidence thus far secured indicates that its use is not absolutely necessary and that it will not be profitable after adequate provision is made for decaying organic matter, since this will necessitate returning to the soil either all produce except the grain (in grain farming) or the manure produced in live-stock farming. (Where hay or straw are sold, manure should be bought.)

On soils which are subject to surface washings, including especially the yellow silt loam of the upland timber area, and to some extent the yellow-gray silt loam, and other more rolling areas, the supply of minerals in the subsurface and subsoil (which gradually renew the surface soil) tend to provide for a low-grade system of permanent agriculture if some use is made of legume plants, as in long rotations with much pasture, because both the minerals and nitrogen are thus provided in some amount almost permanently; but where such lands are farmed under such a system not more than two or three grain crops shoud be grown during a period of ten or twelve years, the land being kept in pasture most of the time; and where the soil is acid a liberal use of limestone, as top dressings if necessary, and occasional reseeding with clovers will benefit both the pasture and indirectly the grain crops.

ADVANTAGE OF CROP ROTATION AND PERMANENT SYSTEMS

It should be noted that clover is not likely to be well infected with the clover bacteria during the first rotation on a given farm or field where it has not been grown before within recent years; but even a partial stand of clover the first time will probably provide a thousand times as many bacteria for the next clover crop as one could afford to apply in artificial inoculation, for a single root-tubercle may contain a million bacteria developed from one during the season's growth.

This is only one of several advantages of the second course of the rotation over the first course. Thus the mere practice of crop rotation is an advantage, especially in helping to rid the land of insects and foul grass and weeds. The deep-rooting clover crop is an advantage to subsequent crops because of that characteristic. The larger applications of organic manures (made possible by the larger crops) are a great advantage; and in systems of permanent soil improvement, such as are here advised and illustrated, more limestone and more phosphorus are provided than are needed for the meager or moderate crops produced during the first rotation, and consequently the crops in the second rotation have the advantage of such accumulated residues (well incorporated with the plowed soil) in addition to the regular applications made during the second rotation.

This means that these systems tend positively toward the making of richer lands. The ultimate analyses recorded in the tables give the absolute invoice of these Illinois soils. They show that most of them are positively deficient only in limestone, phosphorus, and nitrogenous organic matter; and the accumulated information from careful and long-continued investigations in different parts of the United States clearly establish the fact that in general farming these essentials can be supplied with greatest economy and profit by the use of ground natural limestone, very finely ground natural rock phosphate, and legume crops to be plowed under directly or in farm manure. On normal soils no other applications are absolutely necessary, but, as already explained, the addition of some soluble salt in the beginning of a system of improvement on some of these soils produces temporary benefit, and if some inexpensive salt, such as kainit, is used, it may produce sufficient increase to more than pay the added cost.

The Potassium Problem

As reported in Illinois Bulletin 123, where wheat has been grown every year for more than half a century at Rothamsted, England, exactly the same increase was produced (5.6 bushels per acre), as an average of the first 24 years, whether potassium, magnesium, or sodium was applied, the rate of application per annum being 200 pounds of potassium sulfate and molecular equivalents of magnesium sulfate and sodium sulfate. As an average of 60 years (1852 to 1911) the yield of wheat has been 12.7 bushels on untreated land, 23.3 bushels where 86 pounds of nitrogen and 29 pounds of phosphorus per acre per annum were applied; and, as further additions, 85 pounds of potassium raised the yield to 31.3 bushels; 52 pounds of magnesium raised it to 29.2 bushels; and 50 pounds of sodium raised it to 29.5 bushels. Where potassium was applied the average wheat crop removed 40 pounds of that element in the grain and straw, or three times as much as would be removed in the grain only for such crops as are suggested in Table A. The Rothamsted soil contained an abundance of limestone, but no organic matter was provided except the little in the stubble and roots of the wheat plants.

On another field at Rothamsted the average yield of barley for 60 years (1852 to 1911) has been 14.2 bushels on untreated land, 38.1 bushels where 43 pounds of nitrogen and 29 pounds of phosphorus have been applied per acre per annum; while the further addition of 85 pounds of potassium, 19 pounds of magnesium, and 14 pounds of sodium (all in sulfates) raised the average yield to 41.5 bushels, but, where only 70 pounds of sodium were applied in addition to the nitrogen and phosphorus, the average has been 43.0 bushels. Thus, as an average of 60 years, the use of sodium produced 1.8 bushels less wheat and 1.5 bushels more barley than the use of potassium, with both grain and straw removed and no organic manures returned.

In recent years the effect of potassium is becoming much more marked than that of sodium or magnesium, on the wheat crop; but this must be expected to occur in time where no potassium is returned in straw or manure, and no provision made for liberating potassium from the supply still remaining in the soil. If more than three-fourths of the potassium removed were returned in the straw (see Table A), and if the decomposition products of the straw have power to liberate additional amounts of potassium from the soil, the necessity of purchasing potassium in a good system of farming on such land is very remote.

While about half of the potassium, nitrogen, and organic matter, and about one-fourth of the phosphorus, contained in manure, will be lost by three or four months' exposure in the ordinary pile in the barn yard, there is practically no loss if plenty of absorbent bedding is used on cement floors, and if the manure is hauled to the field and spread within a day or two after it is produced. Again, while the animals destroy two-thirds of the organic matter and retain one-fourth of the nitrogen and phosphorus in average live-stock farming, they retain less than one-tenth of the potassium, from the food consumed; so that the actual loss of potassium in the products sold from the farm, either in grain farming or in live-stock farming, is wholly negligible on land containing 25,000 pounds or more of potassium in the surface 6⅔ inches.

The removal of one inch of soil per century by surface washing (which is likely to occur wherever there is satisfactory surface drainage and frequent cultivation) would permanently maintain the potassium in grain farming by renewal from the subsoil, provided one-third of the potassium is removed by cropping before the soil is carried away.

From all of these facts it will be seen that the potassium problem is not one of addition but of liberation; and the Rothamsted records show that for many years other soluble salts have practically the same power as potassium to increase crop yields in the absence of sufficient decaying organic matter. Whether this action relates to supplying or liberating potassium for its own sake, or to the power of the soluble salt to increase the availability of phosphorus or other elements, it is not known, but where much potassium is removed, as in the entire crops at Rothamsted, with no return of organic residues, probably the soluble salt functions in both ways.

As an average of 112 separate tests conducted in 1907, 1908, 1909 and 1910 on the Fairfield experiment field, an application of 200 pounds of potassium sulfate, containing 85 pounds of potassium costing $5.10, increased the yield of corn by 9.3 bushels per acre; while 600 pounds of kainit, containing only 60 pounds of potassium and costing $4.00, gave an increase of 10.7 bushels. Thus, at 40 cents a bushel for corn, the kainit has paid for itself; but these results, like those at Rothamsted, were secured where no adequate provision had been made for decaying organic matter.

Additional experiments at Fairfield include an equally complete test with potassium sulfate and kainit on land to which 8 tons per acre of farm manure had been applied. As an average of 112 tests with each material, the 200 pounds of potassium sulfate increased the yield of corn by 1.7 bushels, while the 600 pounds of kainit also gave an increase of 1.7 bushels. Thus, where organic manure was supplied, very little effect was produced by the addition of either potassium sulfate or kainit; in part perhaps because the potassium removed in the crops is mostly returned in the manure if properly cared for; and perhaps in larger part because the decaying organic matter helps to liberate and hold in solution other plant food elements, especially phosphorus.

In laboratory experiments at the Illinois Experiment Station, it has been shown that potassium salts and most other soluble salts increase the solubility of the phosphorus in soil and in rock phosphate as determined by chemical analysis; also that the addition of glucose with rock phosphate in pot-culture experiments increases the availability of the phosphorus, as measured by plant growth, altho the glucose consists only of carbon, hydrogen, and oxygen, and thus contains no plant food of value.

If we remember that, as an average, live stock destroy two-thirds of the organic matter of the food consumed, it is easy to determine from Table A that more organic matter will be supplied in a proper grain system than in a strictly live-stock system; and the evidence thus far secured from older experiments at the University and at other places in the state indicates that if the corn stalks, straw, clover, etc., are incorporated with the soil as soon as practicable after they are produced (which can usually be done in the late fall or early spring), there is little or no difficulty in securing sufficient decomposition in our humid climate to avoid serious interference with the capillary movement of the soil moisture, a common danger from plowing under too much coarse manure of any kind in the late spring of a dry year.

If, however, the entire produce of the land is sold from the farm, as in hay farming, or when both grain and straw are sold, of course the draft on potassium will then be so great that in time it must be renewed by some sort of application. As a rule, such farmers ought to secure manure from town, since they furnish the bulk of the material out of the which manure is produced.

CALCIUM AND MAGNESIUM

When measured by the actual crop requirements for plant food, magnesium and calcium are more limited in some Illinois soils than potassium. But with these elements we must also consider the loss by leaching. As an average of 90 analyses* of Illinois well-waters drawn chiefly from glacial sands, gravels, or till, 3 million pounds of water (about the average annual drainage per acre for Illinois) contained 11 pounds of potassium, 130 of magnesium, and 330 of calcium. These figures are very significant, and it may be stated that if the plowed soil is well supplied with the carbonates of magnesium and calcium, then a very considerable proportion of these amounts will be leached from that stratum. Thus the loss of calcium from the plowed soil of an acre at Rothamsted, England, where the soil contains plenty of limestone, has averaged more than 300 pounds a year as determined by analyzing the soil in 1865 and again in 1905. And practically the same amount of calcium was found by analyzing the Rothamsted drainage waters.

Common limestone, which is calcium carbonate ($CaCO_3$), contains, when pure, 40 percent of calcium, so that 800 pounds of limestone are equivalent to 320 pounds of calcium. Where 10 tons per acre of ground limestone were applied at Edgewood, Illinois, the average annual loss during the next ten years amounted to 790 pounds per acre. The definite data from careful investigations seems to be ample to justify the conclusion that where limestone is needed at least 2 tons per acre should be applied every 4 or 5 years.

It is of interest to note that thirty crops of clover of four tons each would require 3,510 pounds of calcium, while the most common prairie land of southern Illinois contains only 3,420 pounds of total calcium in the plowed soil of an acre. (See Soil Report No. 1.) Thus limestone has a positive value on some soils for the plant food which it supplies, in addition to its value in correcting soil acidity and in improving the physical condition of the soil. Ordinary limestone (abundant in the southern and western parts of the state) contains nearly 800 pounds of calcium per ton; while a good grade of dolomitic limestone (the more common limestone of northern Illinois) contains about 400 pounds of calcium and 300 pounds of magnesium per ton. Both of these elements are furnished in readily available form in ground dolomitic limestone.

*Reported by Doctor Bartow and associates, of the Illinois State Water Survey.

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

SOIL REPORT NO. 4

SANGAMON COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER,
J. H. PETTIT, AND J. E. READHIMER

URBANA, ILLINOIS, SEPTEMBER, 1912

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*On leave.

SANGAMON COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER, J. H. PETTIT, and J. E. READHIMER

Introduction

About two-thirds of Illinois lies in the corn belt, where most of the prairie lands are black or dark brown in color. In the southern third of the state the prairie soils are largely of a gray color, and this region is better known as the wheat belt, altho wheat is often grown in the corn belt and corn is also a common crop in the wheat belt.

Moultrie county, representing the corn belt; Clay county, which is fairly representative of the wheat belt; and Hardin county, which is taken to represent the unglaciated area of the extreme southern part of the state, were selected for the first Illinois Soil Reports by counties. While these three County Soil Reports were sent to the Station's entire mailing list within the state, Sangamon and other subsequent Reports are sent only to the residents of the county concerned and to any one else upon request.

Each county report is intended to be as nearly complete in itself as it is practicable to make it, and, even at the expense of some repetition, each will contain a general discussion of important fundamental principles to help the farmer and landowner to understand the meaning of the soil fertility invoice for the lands in which he is interested. In Soil Report No. 1, "Clay County Soils", this discussion serves in part as an introduction, while in this and other reports it will be found in the Appendix, but if necessary it should be read and studied in advance of the report proper.

Sangamon county is located in the corn belt and almost wholly within the middle Illinois glaciation, the apparent exception being a small area of about two square miles in the southern part, southeast of Auburn, which has soils peculiar to the transition zone between the lower Illinois and middle Illinois glaciations. This is probably the northern terminus of that zone.

The general topography of the county is undulating or slightly rolling. There are, however, some very flat areas, and also belts of very rolling or hilly land along the larger streams, comprising about 6¼ percent of the entire area of the county. The difference in topography is due mainly to two causes, glacial action and stream erosion. Like most of the state, this county was covered by a glacial ice sheet during what is known as the Glacial Period. During this time snow and ice accumulated in the vicinity of Hudson Bay to such an amount that it flowed southward until a point was reached where the ice melted as rapidly as it advanced.

In flowing across the country the ice gathered up all sorts and sizes of earthy material, including pebbles, boulders, and even large masses of rock. Many of these were carried for hundreds of miles and rubbed against the surface rocks or against each other until ground into powder. When the limit

of advance was reached, where the ice largely melted, all of this material would accumulate in a broad undulating ridge or moraine. When the ice melted away more rapidly than the forward movement, the terminus of the glacier would recede and leave the moraine of boulder clay to mark the outer limit of the ice sheet.

The ice made many advances, and with each advance a terminal moraine was formed. This has left a system of terminal moraines (irregularly concentric with Lake Michigan) having generally a steep outer slope while the inner slope is much less and more gradual.

The material transported by the glacier varied with the character of the rocks over which it passed. Granites, limestones, sandstones, shales, etc., were mixed and ground up together. This mixture of all kinds of boulders, gravel, sand, silt, and clay is called boulder clay, till, or glacial drift (or simply drift). The grinding and denuding power of glaciers is enormous. A mass of ice 100 feet thick exerts a pressure of 40 pounds per square inch, and this ice sheet may have been thousands of feet in thickness.

The materials pushed along in this mass of ice, especially the boulders and pebbles, became powerful agents for grinding and wearing away the surface over which the ice passed. Ridges and hills were rubbed down and valleys filled, and the surface features changed entirely. Occasionally there were hills or ridges sufficiently large or the material composing them was sufficiently resistant to withstand the glacier. In such cases the glacier would flow around or over the obstacle if the ice was thick enough. When the glacier melted, the eminence would be left, in the former case free from drift, while in the latter a thin mantle of drift would cover it. A preglacial ridge in the southwestern part of the county at Lowder, sometimes taken as a glacial moraine, illustrates the latter condition.

A true glacial moraine, called the Buffalo Hart moraine, is located in the eastern part of the county, extending northwest and southeast. It enters from Christian county near Mt. Auburn, extends east of Mechanicsburg, thence to Buffalo, Buffalo Hart, and on to Elkhart in Logan county. The average width is about two miles. It is composed of a large number of more or less prominent knolls, varying from 30 to 80 feet above the surrounding country. Among these knolls are shallow basins, giving the ridge a somewhat peculiar "knob-and-basin" topography. Near Buffalo Hart this ridge was partly forested and considerable erosion has occurred, giving rise to about three square miles of yellow and yellow-gray silt loam. (See also State Map in Bulletin 123.)

A deposit of boulder clay covers the entire county to a depth of from 20 to 80 feet, with an average of about 40 feet. The surface left by the glacier was slightly rolling, without very good drainage, but it was later covered by a deposit of loess.

PHYSIOGRAPHY

Sangamon county lies entirely in the drainage basin of the Sangamon river. The highest part of the county is toward the southwest, near Lowder, on the old preglacial ridge somewhat more than 700 feet above sea level. A corresponding high point is found in the northeast, on the Buffalo Hart moraine, that reaches to nearly 700 feet. The average altitude of the county is near 585 feet. The altitude of the Sangamon river where it leaves the county is 512 feet, while at the east side of the county it is 550 feet.

The valley of the Sangamon river is from 50 to 100 feet below the general upland. This has permitted the small streams entering the river to do considerable erosion, and as a result the land adjacent to the bottom land of the larger streams is cut up into hills and valleys unsuited for ordinary agriculture. Forests had extended their way up the streams and were slowly invading the adjoining prairies, before they were put under cultivation. The influence of the prevailing southwesterly wind may be seen in the greater extension of the forests to the north and east of the protecting streams, as shown in the soil types.

SOIL MATERIAL AND SOIL TYPES

The Illinois glacier covered Sangamon county and left a thick mantle of drift, completely burying the old soil that preceded it. After this a long period elapsed during which a deep soil was formed on the Illinois drift, known as the Old Sangamon Soil. Later other ice invasions of Illinois occurred, but they covered only the northern and northeastern parts of the state. (See State Map in Bulletin 123, Iowan and Wisconsin glaciations.) These ice sheets did not reach Sangamon county, but immense quantities of finely ground rock (rock flour) were carried south by the waters from the melting ice and deposited on the flood plains of the large streams, where it was picked up by the wind and carried over and deposited upon the land, burying the glacial material of the Illinois glaciation and the Sangamon soil to a depth of from 5 to 50 feet or more, the deeper deposit being nearer and on the east side of the streams and opposite the greatest width of bottom land. This wind-blown material, called loess, represents a mixture of all kinds of material over which the glacier passed.

Near the Sangamon river three layers of this deposit may be distinguished. The lower one is typical loess, containing shells and lime concretions. Above this is a stratum of sand of varying thickness, which is overlain by a more clayey form of loess that was probably deposited during the Wisconsin glaciation.

The Sangamon soil may sometimes be seen in cuts as a somewhat dark or bluish sticky clay, or as a weathered zone of yellowish or brownish clay.

More recently the wind has blown sand from the flood plains of the large streams onto the adjacent upland, thus giving rise to 10.9 square miles of sandy soils. After the loessial material was deposited over the surface of the country it was mixed with organic matter to a greater or less extent, and thus gradually changed into soil. Surface washing has made additional modifications.

Table 1 shows the area of each type of soil in the country and its percentage of the total area.

It will be noted that more than half of the entire county is covered with the common prairie land, known as brown silt loam, while the black clay loam, sometimes called "black gumbo", occupying the flat upland prairie, is the second most extensive type.

Nearly 12 percent of the county consists of yellow-gray silt loam, the undulating upland soil once covered with timber; and the more rolling yellow silt loam, also timber upland, is about half as extensive.

Six other upland types aggregate only about 3 percent of the county, and nearly 9 percent consists of bottom land.

TABLE 1.—SOIL TYPES OF SANGAMON COUNTY

Soil type No.	Name of type	Area in square miles	Area in acres	Percent of total area
	(a) Upland Prairie Soils			
426	Brown silt loam.	468.47	299,817	53.87
420	Black clay loam	137.18	87,801	15.77
428	Brown-gray silt loam on tight clay	2.60	1,665	.30
425.1	Black silt loam on clay	10.83	6,928	1.24
	(b) Upland Timber Soils			
434	Yellow-gray silt loam	103.85	66,460	11.93
435	Yellow silt loam	54.23	34,709	6.23
432	Light gray silt loam on tight clay	3.75	2,402	.42
464	Yellow-gray sandy loam	4.64	2,971	.53
465	Yellow sandy loam.	4.85	3,102	.55
481	Dune sand	1.43	914	.15
	(c) Bottom Land			
1426	Deep brown silt loam	77.65	49,696	8.93
	Total area	869.48	556,467	100.00

The accompanying maps show the location and boundary lines of every type of soil in the county, even down to areas of a few acres; and in Table 2 are reported the amounts of organic carbon (the best measure of the organic matter) and the total amounts of the five important elements of plant food contained in the 2 million pounds of the surface soil, corresponding to the plowed soil of an acre about 6⅔ inches deep. In addition, the table shows the amount of limestone present (if any) or the amount of limestone required to neutralize the acidity existing in the soil.*

THE INVOICE AND INCREASE OF FERTILITY IN SANGAMON COUNTY SOILS

SOIL ANALYSIS

In order to avoid complication and confusion in the practical application of the technical information contained in this report, the results are given in the most simplified form. The composition reported for a given soil type is as a rule the average of many analyses, which, like most things in nature, show more or less variation. For all practical purposes the average is most trustworthy and sufficient, as will be seen from Bulletin 123, which reports the general soil survey of the state, and in which are reported many hundred individual analyses of soil samples representing twenty-five of the most important and most extensive soil types in the state.

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but the rate of liberation is governed by many factors, as explained in the Appendix. As there stated, probably no agricultural fact is more generally known by farmers and land-

*The figures given in Table 2 (and in the corresponding tables for subsurface and subsoil) are the averages for all samples analyzed, with the single exception of the limestone for three samples of brown silt loam, one each for surface, subsurface, and subsoil. With seemed unwise to include the abnormal exception in making the averages. type; and it this exception, no limestone was found in analyzing 51 samples of this soil

SOIL SURVEY MAP OF SANGAMON
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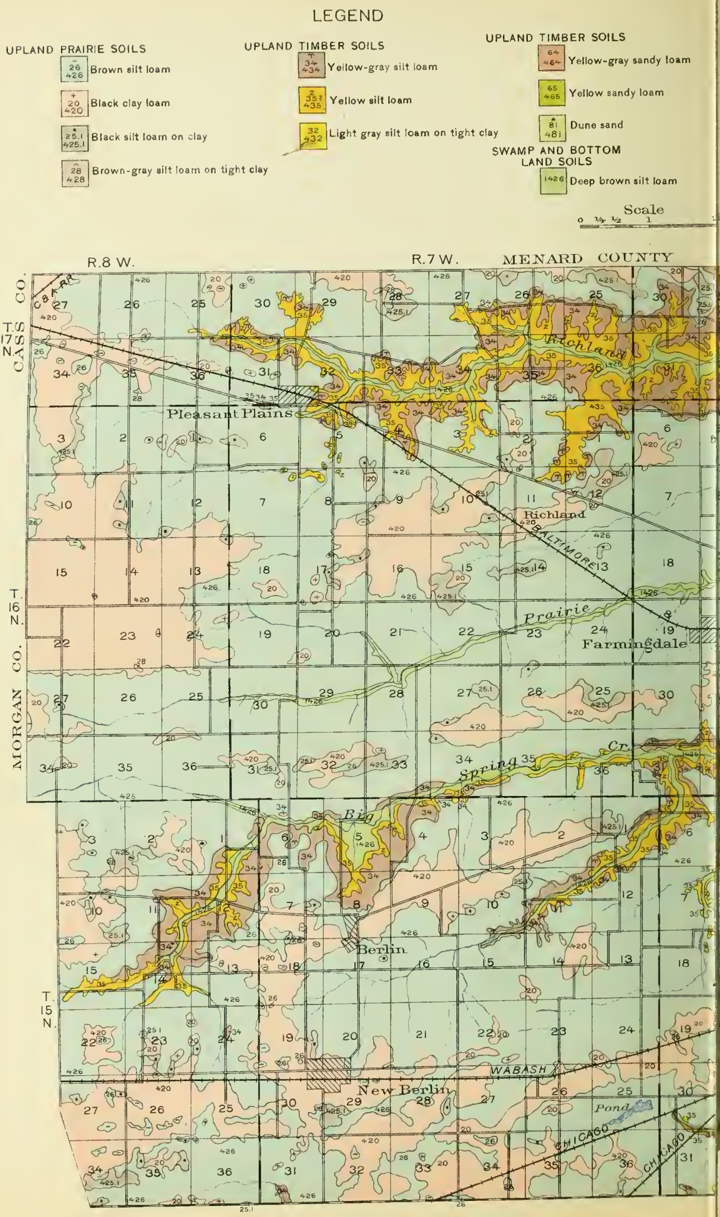

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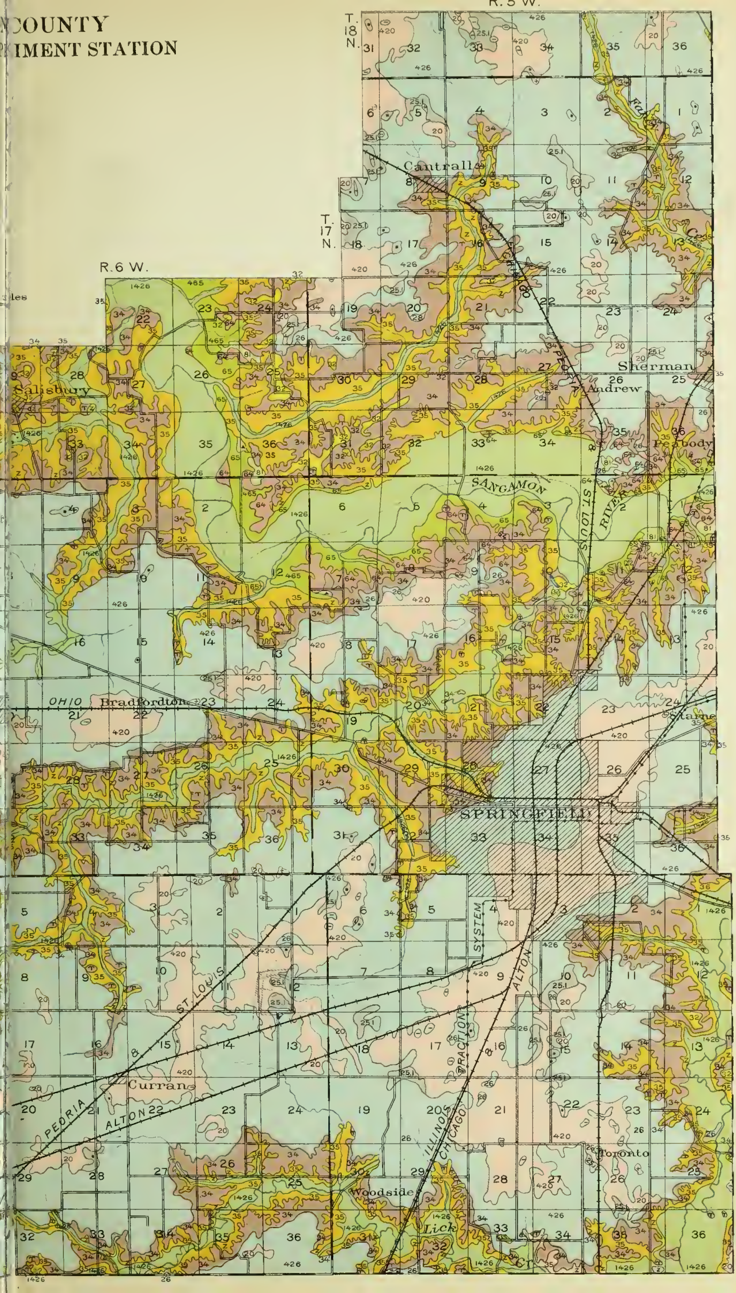


owners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that the productive power of normal soil in humid sections depends upon the stock of plant food contained in the soil and upon the rate at which it is liberated.

The fact may be repeated, too, that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all plants, only one (hydrogen) from water, and seven from the soil, altho nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes), in case the amount liberated from the soil is insufficient; but even these plants (which include the clovers, peas, beans, alfalfa, and vetches), in common with other agricultural plants, secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron and sulfur) and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Table A in the Appendix shows the requirements of large crops for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally from natural sources in sufficient abundance, compared with the amounts needed by plants, so that they are not known ever to limit the yield of crops.)

As stated, the data in Table 2 represent the total amounts of plant food found in two million pounds of the surface soil, which corresponds to an acre of soil about 6⅔ inches deep, including at least as much soil as is ordinarily turned with the plow, and representing that part of the soil with which we incorporate the farm manure, limestone, phosphate, or other fertilizer applied in soil improvement. This is the soil stratum upon which we must depend in large part to furnish the necessary plant food for the production of the crops grown, as will be seen from the information given in the Appendix. Even a rich subsoil has little or no value if it lies beneath a worn-out surface, but if the fertility of the surface soil is maintained at a high point, then the strong and vigorous plants will have power to secure more plant food from the subsurface and subsoil than would be the case with weak, shallow-rooted plants.

By easy computation it will be found that the most common prairie soil of Sangamon county does not contain more than enough total nitrogen in the plowed soil for the production of maximum crops for eight rotations; while the upland timber soils contain as an average less than one-half as much nitrogen as the prairie land.

With respect to phosphorus, the condition differs only in degree, nine-tenths of the soil area of the county containing no more of that element than would be required for fifteen crop rotations if such crop yields were secured as suggested in Table A of the Appendix; and in case of the cereals it will

TABLE 2.—FERTILITY IN THE SOILS OF SANGAMON COUNTY, ILLINOIS

Average pounds per acre in 2 million pounds of surface soil (about 0 to 6⅔ inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone requir'd
	Upland Prairie Soils								
426	Brown silt loam	51680	4070	1030	34620	7470	9280		50
420	Black clay loam	63570	5040	1330	31870	11090	15990	2850	
428	Brown-gray silt loam on tight clay	30490	2700	680	35530	5320	8630	350	
425.1	Black silt loam on clay......	58260	4800	1120	31360	10440	14750	240	
	Upland Timber Soils								
434	Yellow-gray silt loam..	26160	2300	1010	35970	5390	7100		30
435	Yellow silt loam	10240	920	820	40020	7210	6440		470
432	Light gray silt loam on tight clay	19040	1880	720	33000	5280	6740		20
464	Yellow-gray sandy loam...	15000	1640	720	36980	6540	5960		40
465	Yellow sandy loam	11580	1260	620	36640	5020	4240	840	
481	Dune sand..	9140	780	480	23430	3010	4480		20
	Swamp and Bottom-Land Soils								
1426	Deep brown silt loam.. ...	51140	4450	1630	41350	10630	11700	700	

be seen that about three-fourths of the phosphorus taken from the soil is deposited in the grain, while only one-fourth remains in the straw or stalks.

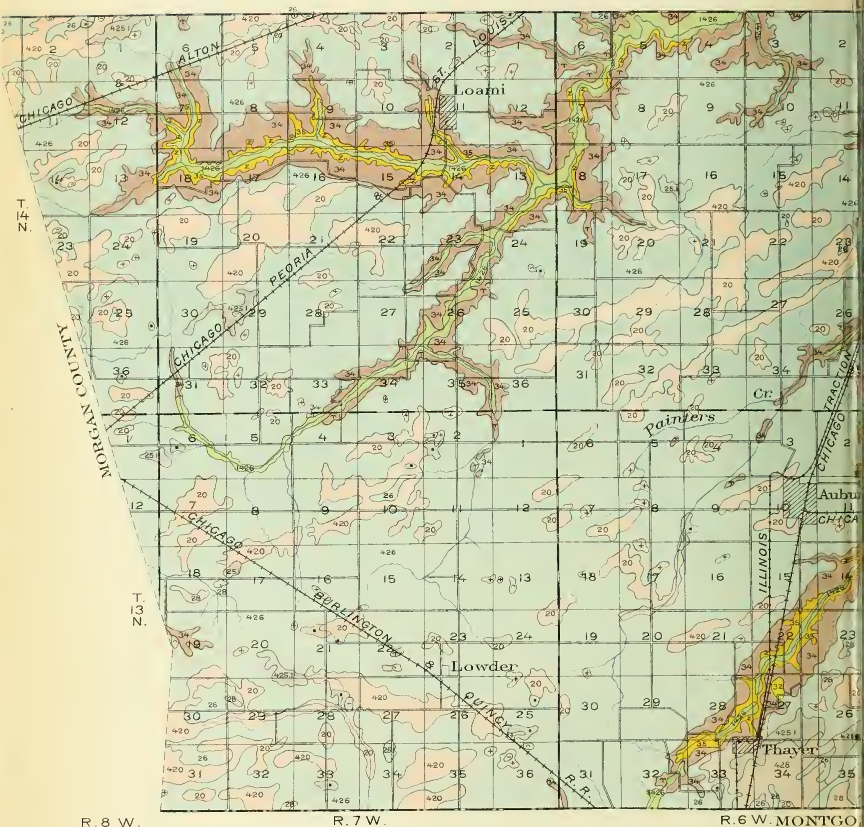
On the other hand, the potassium is sufficient for 25 centuries if only the grain is sold, or for 425 years even if the total crops were removed and nothing returned. The corresponding figures are about 2,000 and 500 years for magnesium, and about 10,000 and 200 years for calcium.

Thus, when measured by the actual crop requirements for plant food, potassium is no more limited than magnesium and calcium, and, as explained in the Appendix, with these elements we must also consider the heavier loss by leaching.

These general statements relating to the total quantities of plant food in the plowed soil certainly emphasize the fact that the supplies of some of these necessary elements of fertility are extremely limited when measured by the needs of large crop yields for even one or two generations of people.

The variation among the different soil types with respect to their content of important plant-food elements is also very marked. Thus, the prairie soils contain from three to five times as much nitrogen as the timber lands of the same topography; and the black clay loam, the richest prairie land, contains twice as much phosphorus as the poorest upland soils. (The black clay loam of the middle Illinois glaciation is lower in phosphorus than the corresponding type in the more recent formations, as the early and the late Wisconsin.)

On the other hand, the most significant fact revealed by the investigation of Sangamon county soils is the low phosphorus content of the common



SOIL SURVEY MAP OF

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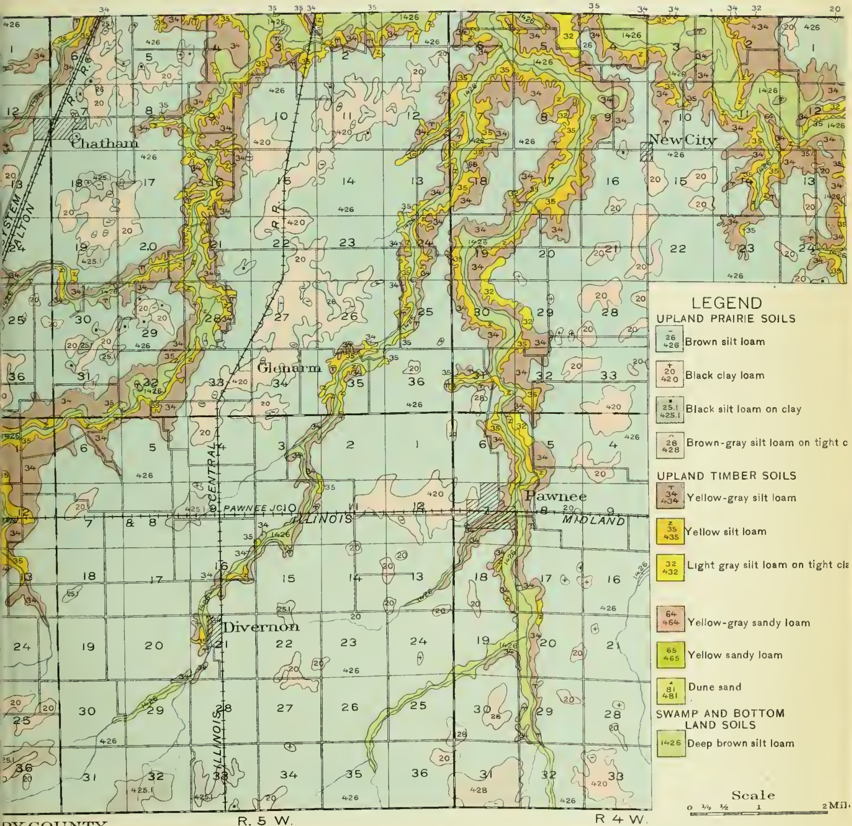


ANGAMON COUNTY

URAL EXPERIMENT STATION

brown silt loam prairie, a type of soil which covers more than one-half of the entire county. The market value of this land is about $200 an acre, and yet an application of $30 worth of fine-ground raw rock phosphate would double the phosphorus content of the plowed soil. Such an application properly made would also double the yield of clover in the near future; and, if the clover was then returned to the soil either directly or in farm manure, the combined effect of phosphorus and nitrogenous organic matter with a good rotation of crops would in time double the yield of corn on most farms.

The average yield of corn for Sangamon county for the ten years 1902 to 1911 was 40.9 bushels per acre;* yet this county occupies a most favored position in the most southern lobe of the corn belt of the United States. Meanwhile, Boone county, on the Wisconsin line, nearly 200 miles farther north, has averaged 41.5 bushels of corn per acre during the same ten years.

With 4,000 pounds of nitrogen in the soil and an inexhaustible supply in the air, with 34,000 pounds of potassium in the same soil and with practically no acidity, the economic loss in farming such land with only 1,000 pounds of total phosphorus in the plowed soil can be appreciated only by the man who fully realizes that the crop yields could be doubled by adding phosphorus,—and without change of seed or season and with very little more work than is now devoted to the fields.

Fortunately, some definite field experiments have already been conducted on this most extensive type of soil in Sangamon county, and also for longer periods on similar soil in several other counties, as at Virginia in Cass county, at Urbana in Champaign county, at Sibley in Ford county, and at Bloomington in McLean county.

RESULTS OF FIELD EXPERIMENTS AT AUBURN

A field of ten acres of common prairie land was selected on the farm of Mr. B. F. Workman, about five miles west of Auburn, on which experiments were begun in 1905. The field was divided into two series of plots, corn being grown on one series for two years and then on the other series, while the first series grew oats one year and clover the next, thus providing for a four-year rotation of corn, corn, oats, and clover, corn being represented every year, and the oats and clover in alternate years. No experimental data were secured from Series 100 during the first two years, but a crop of cowpeas was grown and plowed under on all plots in that series in 1906.

In Table 3 are recorded the results secured from eight plots in each series, four of these plots having received applications of raw rock phosphate, while the other four received no phosphate, but were otherwise treated the same.

It is of special interest to note that the effect of phosphorus on the corn crop is marked whenever the seasonal conditions are favorable for corn. Thus, when the plots not receiving phosphorus have produced 50 bushels or more per acre, the increase from phosphorus has averaged from 7.8 bushels in 1907 to 11.0 bushels in 1908, and to 16.9 bushels in 1911; but, when certain other factors of influence have held the yield of corn below 50 bushels, phosphorus has produced little or no effect, except for the first year, when the low yield was due to a poor stand of corn and not to adverse weather

*Statistical Report, Illinois State Board of Agriculture, December 1, 1911, page 36.

Table 3.—Experiments with Raw Rock Phosphate on Brown Silt Loam Prairie, Auburn Field

Crops and yields per acre			Without phosphorus				With phosphorus				Average gain for phosphorus
Series	Year	Plot No.	2	3	4	5	6	7	8	9	
100	1905	No experiment									
200	1905	Corn, bu.	41.7	39.3	41.7	42.1	48.1	46.3	48.9	49.7	7.0
100	1906	Cowpeas (turned)									
200	1906	Corn, bu.	42.1	40.6	34.9	38.4	42.9	41.3	39.8	37.6	1.4
100	1907	Corn, bu.	54.1	61.9	64.5	61.1	68.6	68.1	69.6	66.4	7.8
200	1907	Oats, bu.	26.6	26.1	25.9	24.2	35.9	30.5	31.3	36.7	7.9
100	1908	Corn, bu.	39.0	51 3	52.6	38.5	54.1	59.2	59 2	53 0	11.0
200	1908	Clover, tons	.91	2.12	1.69	.58	.77	.85	1.98	2.19	.12
100	1909	Oats, bu.	48 1	48.4	52 0	43.3	44.7	50.5	55 5	55.8	3.7
200	1909	Corn, bu.	43 0	48.3	41.4	32.8	36.2	25.8	39.2	48.5	3.9
100	1910	Clover, tons		2 31	1.76	2.25	3.23		3.06	3.06	1.01
200	1910	Corn, bu.	46.0	49.5	45.5	38.6	40.8	44.6	39.9	58.6	1.1
100	1911	Corn, bu.	48.2	60.6	40.0	51 0	57.5	76 1	65.9	68 0	16.9
200	1911	Oats, bu.	40.6	43.0	43.0	36.6	43.3	45.8	55.0	59.1	10.0

Average gain for phosphorus	Corn, bu.	5.9
	Oats, bu.	7.2
	Clover, tons	.57

The cost of phosphorus per acre per annum is $1.87½; but during the seven years the increase produced has not only more than paid the total cost, but the phosphorus content of the treated land has been increased from about 1000 pounds to 1300 pounds per acre of plowed soil.

conditions. As an average of these four years, phosphorus has increased the yield of corn by 10.7 bushels per acre; but when the poor years are included, the average increase is reduced to 5.9 bushels, this figure representing the average of twenty-eight different comparable tests.

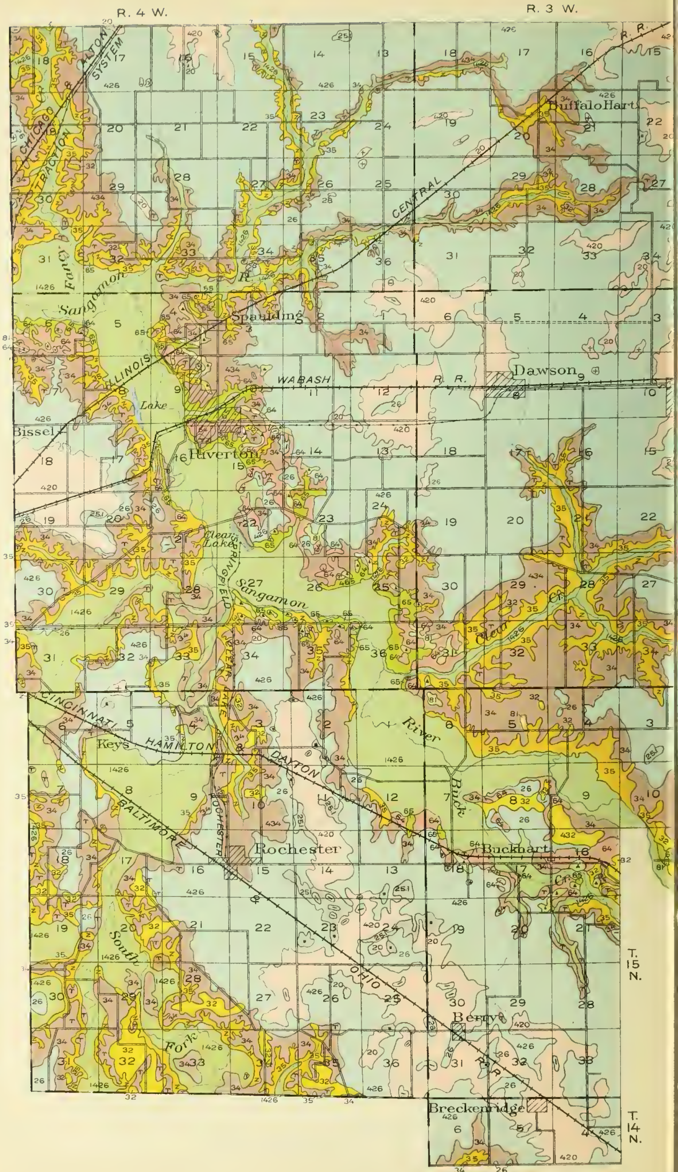
The three crops of oats showed an average increase of 7.2 bushels, and the two clover crops averaged .57 ton more hay on the phosphated land.

On the whole, the data from favorable seasons strongly indicate a cumulative or increasing effect from the phosphate treatment, as we have reason to expect, and as is shown in the latest crops of corn, oats, and clover, the increase amounting to about 25 percent for oats, 34 percent for corn, and 48 percent for clover.

It should be noted that the phosphate has already more than paid its cost; but of equal importance, at least, is the fact that the soil is being positively enriched in that element; and after a few more rotations the amount applied for each year may be very greatly reduced.

On Plots 2, 4, 7, and 9 some cover crop, such as cowpeas or clover, has usually been seeded between the corn rows at the time of the last cultivation. In many cases this has decreased the yield of corn for that year, and the data thus far secured do not justify the practice in central or northern Illinois, especially where oats follow corn.

Since 1908 crop residues, including the corn stalks and oat straw, have been returned to Plots 2 and 7, and the second crop of clover was plowed



SOIL SURVEY MAP OF S
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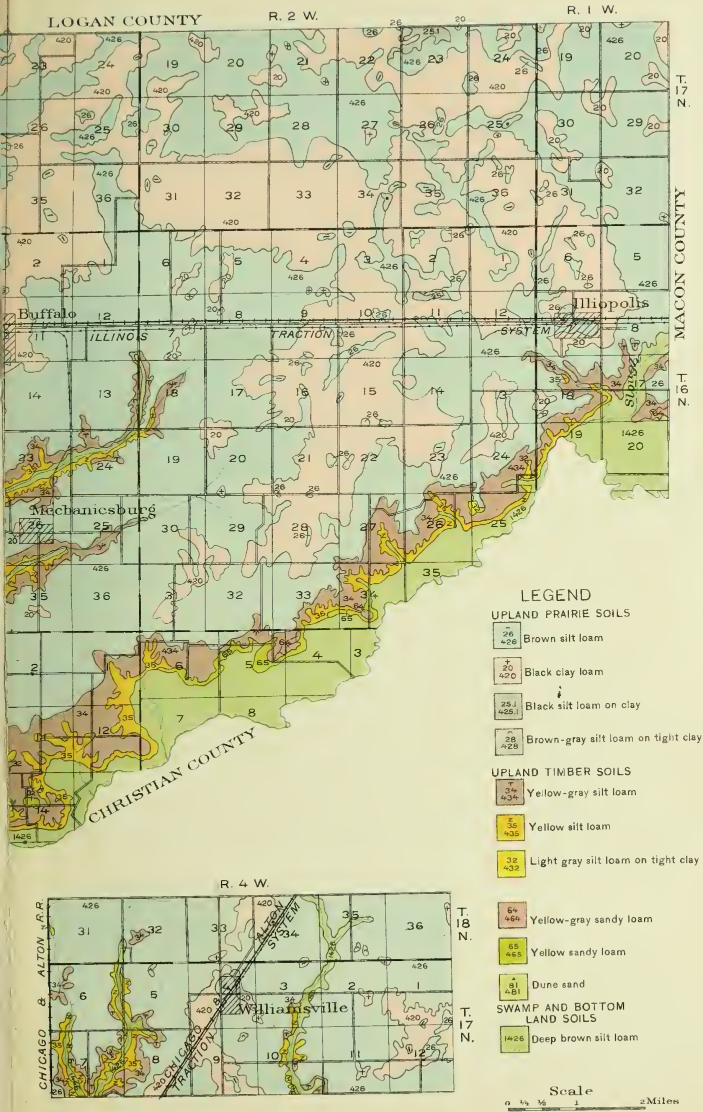


ANGAMON COUNTY
URAL EXPERIMENT STATION

under in 1908, and all clover except the seed in 1910, on these plots. The results thus far secured are not sufficient to justify drawing conclusions in regard to this practice, but it may be noted that the largest yield of corn during the seven years was on Plot 7 in 1911.

Plots 5 and 6 receive no organic manures; but farm manure has been applied to the clover sod and plowed under for corn, since 1907, on plots 3, 4, 8, and 9, the rate of application being as many tons of fresh manure as the number of tons of air-dry produce from the respective plots. As an average, the manure has increased the yield of corn by 4.6 bushels (1907 to 1911) and the yield of oats by 7.7 bushels (1909 to 1911).

RESULTS OF FIELD EXPERIMENTS AT VIRGINIA

The Virginia experiment field was established in 1902, on a ten-acre tract of land belonging to the farm of Mr. George Conover, about three miles southeast of Virginia, in Cass county, on brown silt loam prairie, somewhat above the average of the type in productive power.

A three-year rotation was begun on three different series of plots in order that each crop might be represented every year. During the first six years corn, oats, and cowpeas were grown, but since 1908 the rotation has been corn, oats, and clover.

As an average of two tests each year, for the first 7 years (1902 to 1908), phosphorus, applied at the rate of 25 pounds per acre per annum in 200 pounds of steamed bone meal, produced increases in yield per acre amounting to 6.8 bushels of corn (from 67.3 to 74.1 bushels); while the average yield of oats was increased by .4 bushel (from 43.9 to 44.3 bushels), and the average yield of hay was increased by only .04 ton (from 2.13 to 2.17 tons per acre).

During the next three years (1909 to 1911) the phosphorus increased the average yields by 10.5 bushels of corn (from 70.2 to 80.7 bushels), by 13.1 bushels of oats (43.3 to 56.4 bushels), and by .69 ton of hay (1.42 to 2.11 tons per acre).

It is of interest to compare the seven years' results at Auburn with the first seven years' results at Virginia, the two fields being on the same soil type in the same soil area. When the Virginia experiments were begun, one ton of steamed bone meal, containing 250 pounds of phosphorus (which is the amount applied to one acre in ten years at Virginia), cost less than $25, but in recent years the price has been advanced to $28 to $30 per ton. Thus, at safe prices for produce, the bone meal fell far short of paying its cost during the first seven years at Virginia, altho it much more than paid for the annual expense during the next three years.

At Auburn two and one-half times as much phosphorus is applied in raw rock phosphate at $7.50 per ton, but the annual cost is only $1.87½ per acre, compared with $2.50 to $3.00 for the bone meal used at Virginia.

On the other hand, the results ultimately secured at Virginia were to be expected, because the chemical analysis of the soil shows that phosphorus is not abundant, and its continued use must finally produce marked increases in crop yields in good systems of farming. The fact is that the first limiting element on the Virginia field was not phosphorus but nitrogen; and, this being the case, no marked effect could be produced by phosphorus until the

nitrogen was relatively increased, which has been gradually accomplished by the use of legume crops and farm manure.

In another series of experiments on the Virginia field, commercial nitrogen is applied in a four-year rotation of corn, corn, oats, and wheat. Counting the corn at 35 cents a bushel, oats at 30 cents, and wheat at 70 cents, we find that 100 pounds of nitrogen per acre per annum (in dried blood) produced $42.31 increase in ten years; the yearly addition of 25 pounds of phosphorus in 200 pounds of steamed bone meal raised the increase to $58.96; and 40 pounds of potassium per annum, together with the nitrogen and phosphorus, raised the total increase to $60.67.

If we count the cost at 15 cents a pound for nitrogen, 10 cents a pound for phosphorus, and 6 cents a pound for potassium, we find that for each dollar invested the nitrogen paid back 28 cents, the phosphorus 67 cents, and the potassium 7 cents. As an average of the four years 1908 to 1911, the phosphorus, costing $2.50 per annum, paid back $3.15 under these conditions.

During six of the ten years, corn was grown in both of the rotation systems at Virginia. In the four-year rotation, without legumes or manure, the average yield was 50.4 bushels of corn per acre where lime and bone meal were applied, but, where these materials were applied in the three-year rotation, the six-year average yield of corn was 74.6 bushels in the grain system, with some crop residues plowed under, and 77.0 bushels per acre where farm manure was applied in addition to the lime and phosphorus.

Thus legumes in rotation and some crop residues plowed under in grain farming increased the six-year average yield of corn by 24.2 bushels, and farm manure and legumes in rotation increased the yield by 26.6 bushels; while 100 pounds of commercial nitrogen in about 800 pounds of dried blood, costing $15 to $20 per acre per annum, increased the yield by only 19.5 bushels. (The lime and phosphorus were provided alike on all plots involved in these comparisons.)

At least two very important lessons are taught by these results from the Virginia field: First, when nitrogen has become the limiting element in a soil, nothing else can take its place, and, even tho phosphorus may also be deficient, its addition will not produce marked or profitable results until provision is made to raise the nitrogen limit. Second, the growing of legumes in rotation on the farm and the use of crop residues or farm manure may produce even better results than high-priced commercial nitrogen.

RESULTS OF FIELD EXPERIMENTS AT URBANA

A three-year rotation of corn, oats, and clover was begun on the North Farm at the University of Illinois in 1902, on three fields of typical brown silt loam prairie land which, after twenty years or more of pasturing, had grown corn in 1895, 1896 and 1897 (when careful records were kept of the yields produced), and had then been cropped with clover and grass on one field, oats on another, and oats, cowpeas, and corn on the third field, till 1901.

As an average of the three years 1902 to 1904, phosphorus increased the crop yield per acre by .68 ton of clover, 8.8 bushels of corn, and 1.9 bushels of oats.

During the second three years, 1905-1907, phosphorus produced average increases of .79 ton of clover, 13.2 bushels of corn, and 11.9 bushels of oats.

During the third course of the rotation, 1908-1910, the average increases produced by phosphorus were 1.05 tons of clover, 18.7 bushels of corn, and 8.4 bushels of oats.

For convenient reference the results are summarized in Table 4.

TABLE 4.—EFFECT OF PHOSPHORUS ON BROWN SILT LOAM AT URBANA
(Average increase per acre)

Rotation	Years	Corn, bu.	Oats, bu.	Clover, tons	Value of increase	Cost of treatment*
First	1902,-3,-4	8.8	1.9	.68	$ 7.73	$ 7.50
Second	1905,-6,-7	13.2	11.9	.79	12.93	7.50
Third.	1908,-9,-10	18.7	8.4	1.05	15.37	7.17

*Prices used are 35 cents a bushel for corn, 30 cents for oats, $6.00 a ton for clover hay, 10 and 3 cents a pound for phosphorus in bone meal and rock phosphate, respectively.

PLATE 1. WHEAT IN 1911 ON URBANA FIELD
COVER CROPS AND CROP RESIDUES PLOWED UNDER
AVERAGE YIELD, 35.2 BUSHELS PER ACRE

Wheat is grown on the University South Farm in a rotation experiment started more recently. As an average of the last four years, 1908-1911, raw rock phosphate (with no previous applications of bone meal) has increased the yield of wheat by 10.3 bushels per acre; and here too the phosphorus has paid back about twice its cost, as an average of the last four years, the cost being \$1.87½, and the value of the increase \$3.28 per acre per annum, wheat being valued at 70 cents a bushel and other crops as noted above. These are the average results from two systems of farming, one known as grain farming, and the other as live-stock farming.

In the grain system of farming, the yield of wheat in 1911 was 35.2 bushels per acre where cover crops and crop residues have been plowed under without the use of phosphorus; but where rock phosphate has been used the average yield was 50.1 bushels in the same system. (See Plates 1 and 2.)

PLATE 2. WHEAT IN 1911 ON URBANA FIELD
COVER CROPS AND CROP RESIDUES PLOWED UNDER
FINE-GROUND ROCK PHOSPHATE APPLIED
AVERAGE YIELD, 50.1 BUSHELS PER ACRE

In the live-stock farming, the yield of wheat in 1911 was 34.2 bushels where manure and cover crops are used without phosphate, and 51.8 bushels, as an average where rock phosphate is used in connection with the live-stock system. (See Plates 3 and 4.)

These results emphasize the cumulative effect of permanent systems of soil improvement.

RESULTS OF EXPERIMENTS ON SIBLEY FIELD

Table 5 gives results obtained during the past ten years from the Sibley soil experiment field, located in Ford county on typical brown silt loam prairie of the Illinois corn belt.

Previous to 1902 this land had been cropped with corn and oats for many years under a system of tenant farming and the soil had become somewhat deficient in active organic matter. While phosphorus was the limiting ele-

PLATE 3. WHEAT IN 1911 ON URBANA FIELD
COVER CROPS AND FARM MANURE PLOWED UNDER
AVERAGE YIELD, 34.2 BUSHELS PER ACRE

ment of plant food, the supply of nitrogen becoming available annually was but little in excess of the phosphorus, as is well shown by the corn yields for 1903, when phosphorus produced an increase of 8 bushels, nitrogen without phosphorus produced no increase, but nitrogen and phosphorus increased the yield by 15 bushels.

After six years of additional cropping, however, nitrogen appears to have become the most limiting element, the increase in 1907 being 9 bushels from nitrogen and only 5 bushels from phosphorus, while both together produced an increase of 33 bushels of corn. By comparing the corn yields for the four years 1902, 1903, 1906 and 1907, it will be seen that the untreated land has apparently grown less productive, whereas on land receiving both phosphorus and nitrogen the yield has appreciably increased, so that in 1907, when the untreated rotated land produced only 34 bushels of corn per acre, a yield of

PLATE 4. WHEAT IN 1911 ON URBANA FIELD
COVER CROPS AND FARM MANURE PLOWED UNDER
FINE-GROUND ROCK PHOSPHATE APPLIED
AVERAGE YIELD, 51.8 BUSHELS PER ACRE

72 bushels, or more than twice as much, was produced where lime, nitrogen, and phosphorus had been applied, altho these two plots produced exactly the same yield (57.3 bushels) in 1902.

Even in the unfavorable season of 1910, the highest yielding plot exceeded that of 1902, while the untreated land produced less than half as much. The prolonged drouth of 1911 resulted in almost a failure of the corn crop, but nevertheless the effect of soil treatment is seen. Phosphorus appears to have been the first limiting element again in 1909, 1910, and 1911.

In the lower part of Table 5 are shown the total values per acre of the ten crops from each of the ten different plots, the amounts varying from $147.41 to $227.46; also the value of the increase produced above the untreated land, corn being valued at 35 cents a bushel, oats at 30 cents and wheat at 70 cents. Phosphorus without nitrogen produced $27.74 in addition to the increase by lime; and, with nitrogen, phosphorus produced

TABLE 5.—CROP YIELDS IN SOIL EXPERIMENTS, SIBLEY FIELD

Brown silt loam prairie Early Wisconsin glaciation		Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911
Plot	Soil treatment applied	Bushels per acre									
101	None	57.3	50.4	74.4	29.5	36.7	33.9	25.9	25.3	26.6	20.7
102	Lime	60.0	54.0	74.7	31.7	39.2	38.9	24.7	28.8	34.0	22.2
103	Lime, nitrogen	60.0	54.3	77.5	32.8	41.7	48.1	36.3	19.0	29.0	22.4
104	Lime, phosphorus	61.3	62.3	92.5	36.3	44.8	43.5	25.6	32.2	52.0	31.6
105	Lime, potassium	56.0	49.9	74.4	30.2	37.5	34.9	22.2	23.2	34.2	21.6
106	Lime, nitrogen, phosphorus	57.3	69.1	88.4	45.2	68.5	72.3	45.6	33.3	55.6	35.3
107	Lime, nitrogen, potassium	53 3	51.4	75.9	37.7	39.7	51.1	42.2	25.8	46.2	20.1
108	Lime, phosphorus, potassium	58.7	60.9	80.0	39.8	41.5	39.8	27.2	28.5	43.0	31.8
109	Lime, nitrogen, phosphorus, potassium	58.7	65.9	82.5	48.0	69.5	80.1	52.8	35.0	58.0	35.7
110	Nitrogen, phosphorus, potassium	60.0	60.1	85.0	48.5	63.3	72.3	44.1	30.8	64.4	31.5

VALUE OF CROPS PER ACRE IN TEN YEARS

Plot	Soil treatment applied	Total value of ten crops	Value of increase
101	None	$147.41	
102	Lime	159.07	$11.66
103	Lime, nitrogen	159.83	12.42
104	Lime, phosphorus	186.81	39.40
105	Lime, potassium	148.29	.88
106	Lime, nitrogen, phosphorus	220.49	73.08
107	Lime, nitrogen, potassium	171.51	24.10
108	Lime, phosphorus, potassium	176.46	29.05
109	Lime, nitrogen, phosphorus, potassium	227.46	80.05
110	Nitrogen, phosphorus, potassium	217.31	69.90

$60.66 in addition to the increase by lime and nitrogen. The results show that in 23 cases out of 40 the addition of potassium decreased the crop yields.

By comparing Plots 101 and 102, and also 109 and 110, it will be seen that the average increase by lime was $10.90, or more than $1.00 an acre a year, suggesting that the time is near when limestone must be applied to these brown silt loam soils.

RESULTS OF EXPERIMENTS ON BLOOMINGTON FIELD

Space is taken to insert Table 6, giving all of the results thus far obtained from the Bloomington soil experiment field, which is also located on the brown silt loam prairie soil of the Illinois corn belt.

The general results of the ten years' work on the Bloomington field tell the same story as those from the Sibley field. The rotations differed by the use of clover and by discontinuing the use of commercial nitrogen, after 1905, on the Bloomington field, in consequence of which phosphorus without commercial nitrogen (Plot 104) produced an even larger increase (80.62) than was produced by phosphorus over nitrogen on the Sibley field (see Plots 103 and 106).

It should be stated that a draw runs near Plot 110 on the Bloomington field and the crops on that plot are sometimes damaged by overflow or imperfect drainage; also that in 1902 the stand of corn on the Bloomington field was poor, tho fairly uniform. Otherwise all results reported in Tables 5 and 6, including 200 tests, are considered reliable, and they furnish much information and instructive comparisons.

Wherever nitrogen was provided, either by direct application or by the use of legume crops, the addition of the element phosphorus produced very marked increases, the average value being $70.64 for the ten years, or $7.06 an acre a year. This is $4.56 above its cost in 200 pounds of steamed bone meal, the form in which is was applied to these fields. On the other hand, the use of phosphorus without nitrogen will not maintain the fertility of the soil (see Plots 104 and 106, Sibley field); and a liberal use of clover or other legumes is suggested as the only practical and profitable method of supplying the nitrogen, the clover to be plowed under, either directly or as manure, preferably in connection with the phosphorus applied, especially if raw rock phosphate is used.

From the best treated plots 140 pounds per acre of phosphorus have been removed from the soil in the ten crops. This is equal to 12 percent of the total phosphorus contained in the surface soil of an acre of the untreated land. In other words, if such crops could be grown for 80 years they would require as much phosphorus as the total supply in the ordinary plowed soil. The results plainly show, however, that without the addition of phosphorus such crops cannot be grown year after year. Where no phosphorus was applied, the crops removed only 95 pounds of phosphorus in ten years, equivalent to only 8 percent of the total amount (1,200 pounds) in the surface soil at the beginning (1902). The total phosphorus applied from 1902 to 1911 amounted to 250 pounds per acre.

TABLE 6.—CROP YIELDS IN SOIL EXPERIMENTS, BLOOMINGTON FIELD

Plot	Brown silt loam prairie; early Wisconsin glaciation	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Corn 1908	Oats 1909	Clover 1910†	Wheat 1911
	Soil treatment applied	Bushels or tons per acre									
101	None	30.8	63.9	54.8	30.8	.39	60.8	40.3	46.4	1.56	22.5
102	Lime	37.0	60.3	60.8	28.8	.58	63.1	35.3	53.6	1.09	22.5
103	Lime, nitrogen	35.1	59.5	69.8	30.5	.46	64.3	36.9	49.4	(.83)	25.6
104	Lime, phosphorus	41.7	73.0	72.7	39.2	1.65	82.1	47.5	63.8	4.21	57.6
105	Lime, potassium	37.7	56.4	62.5	33.2	.51	64.1	36.2	45.3	1.26	21.7
106	Lime, nitrogen, phosphorus	43.9	77.6	85.3	50.9	*	78.9	45.8	72.5	(1.67)	60.2
107	Lime, nitrogen, potassium	40.4	58.9	66.4	29.5	.81	64.3	31.0	51.1	(.33)	27.3
108	Lime, phosphorus, potassium	50.1	74 8	70.3	37.8	2.36	81.4	57.2	59.5	3.27	54.0
109	Lime, nitrogen, phosphorus, potassium	52.7	80.9	90.5	51.9	*	88.4	58.1	64.2	(.42)	60.4
110	Nitrogen, phosphorus, potassium	52.3	73.1	71.4	51.1	*	78.0	51.4	55.3	(.60)	61.0

Value of Crops per Acre in Ten Years

Plot	Soil treatment applied	Total value of ten crops	Value of increase
101	None	$147.90	
102	Lime	148.75	$ .85
103	Lime, nitrogen (see text)	151.30	3.40
104	Lime, phosphorus	229.37	81.47
105	Lime, potassium	149.43	1.53
106	Lime, nitrogen, phosphorus	221.30	73.40
107	Lime, nitrogen, potassium	149.96	2.06
108	Lime, phosphorus, potassium	229.20	81.30
109	Lime, nitrogen, phosphorus, potassium	225.57	77.67
110	Nitrogen, phosphorus, potassium	209.26	61 36

*Clover smothered out by previous very heavy wheat crop. After the clover hay was harvested all ten of the plots were seeded to cowpeas and the crop was plowed under later on all plots as green manure for the 1907 corn crop.

†The figures in parentheses represent bushels of clover seed; the others, tons of clover hay (in two cuttings) in 1910.

THE SUBSURFACE AND SUBSOIL

In Tables 7 and 8 are recorded the amounts of plant food in the subsurface and the subsoil, but it should be remembered that these supplies are of little value unless the top soil is kept rich. Probably the most important information contained in Tables 7 and 8 is that the upland timber soils are usually more strongly acid in the subsurface and subsoil than in the surface, thus emphasizing the importance of having plenty of limestone in the surface soil to neutralize the acid moisture which rises from the lower strata by capillary action during the periods of partial drouth, which are also critical periods in the life of such plants as clover. Thus, while the common brown silt loam prairie soil is practically neutral, the upland soils that are or were timbered are already in need of limestone as a rule; and, as already explained, they are much more deficient in phosphorus and nitrogen than the common prairie.

TABLE 7.—FERTILITY IN THE SOILS OF SANGAMON COUNTY, ILLINOIS

Average pounds per acre in 4 million pounds of subsurface soil (about $6\frac{2}{3}$ to 20 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone requir'd
				Upland Prairie Soils					
426	Brown silt loam	69390	5740	1760	68290	17790	17850		100
420	Black clay loam	73730	5980	2070	63730	22830	27060	3260	
428	Brown-gray silt loam on tight clay	31680	2760	1120	70660	15180	16880		100
425.1	Black silt loam on clay.	67660	5540	1780	63500	22140	24800	1760	
				Upland Timber Soils					
434	Yellow-gray silt loam.. .	16880	2150	1760	73250	14570	12170		390
435	Yellow silt loam	13460	1540	1880	74780	16920	11400		2080
432	Light gray silt loam on tight clay	12000	2040	1280	64440	12640	10000		920
464	Yellow-gray sandy loam.	17880	2000	1760	68480	16560	8920		1760
465	Yellow sandy loam.........	5760	1440	1720	77200	19080	9800		400
481	Dune sand......	5090	690	790	41410	6520	8480		30
				Swamp and Bottom-Land Soils					
1426	Deep brown silt loam..	73870	6640	2450	78730	23110	22350	650	

TABLE 8.—FERTILITY IN THE SOILS OF SANGAMON COUNTY, ILLINOIS

Average pounds per acre in 6 million pounds of subsoil (about 20 to 40 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone requir'd
				Upland Prairie Soils					
426	Brown silt loam	39610	4090	2330	99930	38860	29750		180
420	Black clay loam	30710	2990	3070	93620	47060	89180	189150	
428	Brown-gray silt loam on tight clay..	37110	3720	2490	97650	36810	33000		270
425.1	Black silt loam on clay.	28890	3090	2640	96780	39420	41790	30330	
				Upland Timber Soils					
434	Yellow-gray silt loam..	17860	2750	3120	105970	34220	19130		5990
435	Yellow silt loam	13320	1710	1950	109680	31470	21780		840
432	Light-gray silt loam on tight clay..	28500	3300	2220	100740	40020	18540		4140
464	Yellow-gray sandy loam...	14520	1920	3000	110640	28680	27060	50220	
465	Yellow sandy loam..	4980	1920	3060	111900	37560	18660		4680
481	Dune sand.....	7640	1040	1190	62110	9780	12720		50
				Swamp and Bottom-Land Soils					
1426	Deep brown silt loam.. . . .	58580	5200	2740	116580	32720	30140	1160	

INDIVIDUAL SOIL TYPES

(a) UPLAND PRAIRIE SOILS

This class of soils comprises 619 square miles, or 71 percent of the entire area of the county. They are usually dark in color due to a large organic-matter content.

The accumulation of organic matter in the prairie soils is due to the growth of prairie grasses whose net work of roots has been protected from complete decay by imperfect aeration, due to the covering of soil and the moisture it contained. The tops have been burned or have almost completely decayed. From a sample of Champaign county virgin sod of "blue stem", one of the most common prairie grasses, it was determined that an acre of this soil contained 13½ tons of roots to a depth of 7 inches. Many of these roots died each year and by partial decay formed the humus of these dark prairie soils. In upland forests no such quantity of roots is found in the surface soil. The vegetable matter consists of leaves and twigs, which fall upon the surface and either are burned by forest fires or undergo complete decay. There is very little chance for these to become mixed with the soil. As a result the organic-matter content has been lowered by the growth of forests until in some parts of the state a low condition of apparent equilibrium has been reached. All of these prairie soils can be improved by phosphorus and organic manures, and limestone is usually needed. The different types differ chiefly in degree of richness, as is seen from Table 2.

Brown Silt Loam (426)

This is the most important as well as the most extensive type of soil in the county, covering an area of 468.47 square miles, equivalent to 299,817 acres, or 53.87 percent of the entire area.

The type is generally sufficiently rolling for fair surface drainage, altho there are some exceptions where the land is so flat as to require artificial drainage. There are many draws or swales, which are frequently "seepy" and should have at least one line of tile to carry off this seepage water. In some cases two lines of tile may be necessary, one on each side. In the morainal regions and along some of the small streams, the brown silt loam is quite rolling, giving a lighter colored and shallower phase of the type.

The surface soil, 0 to 6⅔ inches, is a brown silt loam, varying from a yellowish brown on the more rolling areas to a dark brown or black on the more nearly level and poorly drained areas. The physical composition varies to some extent but is normally a silt loam containing from about 70 to 80 percent of the different grades of silt.

The clay content, usually 10 to 12 percent, increases as the type approaches black clay loam (420) and becomes greatest in the poorly drained areas. The sand varies from 7 to 15 percent and increases as the bottom land of the large streams is approached.

The organic matter varies from 3½ to 5 percent, with an average of 4½ percent, or 45 tons per acre. Where the type passes into brown-gray silt loam on tight clay (428), the organic matter becomes lower. The growth of forest trees on the upland in this climate reduces the organic matter and ultimately changes the original brown prairie soil into the yellow-gray silt

loam (434). The first trees to invade the dark prairie soils are wild cherry, hackberry, ash, black walnut, and elm. (A black walnut soil is recognized generally by farmers as being one of the best timber soils. It still contains, as a rule, a large amount of the organic matter that accumulated from the prairie grasses.)

The subsurface is represented by a stratum varying from 5 to 14 inches in thickness, the great difference being due to the topography, the stratum being thinner on the more rolling areas and thicker on the level areas. Its physical composition varies in the same way as the surface soil, but generally it contains a slightly larger amount of clay. Locally, the subsurface may become quite heavy, as where the type grades toward the black silt loam on clay. As the type approaches brown-gray silt loam on tight clay (428), the subsurface becomes lighter in color and the upper subsoil becomes heavy or contains more clay.

The color of the subsurface varies from a dark brown or almost black to a light brown or yellowish brown. In general it becomes lighter with depth, passing gradually into the yellow subsoil. The color is due to the organic matter and to the oxidation of the iron.

The organic matter averages 1.8 percent.

The natural subsoil begins at from 12 to 21 inches beneath the surface of the soil and extends to an indefinite depth, but is usually sampled to 40 inches. It varies from a yellow to a drabbish yellow clayey silt. In the more level areas it is of a drab color mottled with yellow blotches, while in the more rolling areas better drainage has allowed better oxidation of the iron to take place, giving the yellow to brownish yellow color. The upper 8 to 12 inches of the subsoil usually contains more clay than the lower part, the coarser material being coarse silt or fine sand.

The subsoil is generally pervious to water, permitting good drainage. Exceptions are found where the type grades toward the brown-gray silt loam on tight clay (428). In this case the subsoil becomes much less pervious, forming rather a poor phase of the type.

While this type is generally in fair physical condition, yet the continuous growing of corn, or corn and oats, with the burning of the stalks and possibly the oat stubble, is destroying the tilth; the soil is becoming more difficult to work, runs together more, and aeration, granulation, absorption, and moisture movement are interfered with. This condition of poor tilth is becoming very serious on many farms and is one of the factors that limit the crop yield.

The remedy is to increase the organic-matter content by plowing under crop residues such as corn stalks, straw, clover, etc., instead of selling them from the farm or burning them, as is often practiced at present. The stalks should be thoroly cut up with a stalk cutter or sharp disk, and turned under. Likewise the straw should be got back onto the land in some practical way, either directly or in manure. Clover should be one of the crops grown in the rotation, and it should be plowed under directly or in manure, instead of being sold as hay, except where manure can be brought back. The addition of fresh organic matter is of even greater importance because of its nitrogen content, and because of its power, as it decays, to liberate potassium from the inexhaustible supply in the soil and phosphorus from the phosphate contained in or applied to the soil, as seen from the results of experiments on the Virginia field reported above. The addition of limestone to this soil is

also becoming important. For permanent maintenance, about 2 tons of limestone and ½ ton of fine-ground rock phosphate should be applied every four or five years, and enough organic matter should be plowed under to furnish the nitrogen required by the crops desired, as shown in Table A of the Appendix. Heavier initial applications of phosphate may well be made.

Black Clay Loam (420)

This type of soil (420) represents the originally swampy and poorly drained areas of the middle Illinois glaciation, and is frequently called "gumbo" because of its sticky character. Its formation in these low places is due to the accumulation of organic matter and the washing in of clay and fine silt from the slightly higher adjoining lands. This type covers 137.18 square miles, equivalent to 87,801 acres, and occupies 15.77 percent of the total area of the county. The topography is so flat that in the larger areas the problem of getting a sufficient outlet for drainage has caused some difficulty.

The surface stratum is a black granular clay loam with from 5 to 6 percent of organic matter. The average is 5.5 percent, or 55 tons per acre. The wet condition of this soil has allowed a greater accumulation of organic matter than on the more rolling areas of brown silt loam (426).

The surface soil is naturally quite granular, and hence pervious to water. This property of granulation is important to all soils, but especially to heavy ones. The soil is kept mellow, and if the granules are destroyed by puddling (as by working or the tramping of stock while the ground is wet), they will be formed again by freezing and thawing or by moisture changes (wetting and drying). These natural agencies produce "slacking", as the process is usually termed. If, however, the organic matter or lime content becomes low, this tendency to granulate grows less and the soil becomes more difficult to work.

The subsurface extends to a depth of from 10 to 16 inches below the surface stratum. It differs from the surface in color, becoming lighter with depth, the lower part of the stratum passing into a drab or yellowish silty clay.

It is quite pervious to water, due to the jointing or checking produced by the shrinkage in times of drouth. The amount of organic matter varies from 2.5 to 4 percent, with an average of 3.1 percent.

The subsoil is usually a drab or dull yellow silty clay, but locally may be a yellow silt or clayey silt. As a rule the iron is not so highly oxidized, due to poor drainage. The subsoil is checked and jointed, making it pervious to water and easy to drain. In many areas the subsoil contains large numbers of concretions of iron hydrate and sometimes of limestone (calcium carbonate).

This type presents many variations. Here as elsewhere the boundary lines between different soil types are not always distinct, but types frequently pass from one to the other very gradually, thus giving an intermediate zone of greater or less width. Variations between black clay loam (420) and brown silt loam (426) are very likely to occur, since these are usually adjoining types. This gives a lighter phase of black clay loam (420), with a smaller organic-matter content than the average, and a heavier phase of brown silt loam (426), with a larger amount of organic matter than usual. (In composition, the gradation zone is intermediate between the two normal

types adjoining.) Again, in some areas of black clay loam there has been enough silty material washed in from the surrounding higher lands to modify the character of the surface soil. This change is taking place more rapidly now with the annual cultivation of soil than formerly when washing was largely prevented by prairie grass.

Drainage is the first requirement of this type, which, altho it has but little slope, yet affords a good chance for tile drainage because of its perviousness. Keeping the soil in good physical condition is very essential, and thoro drainage helps to do this to a great extent. As the organic matter is destroyed by cultivation and nitrification and the lime removed by cropping and leaching, the physical condition becomes poorer, and consequently the working of the soil more difficult. Both the organic matter and the lime tend to develop granulation in the soil. The former should be maintained by turning under manure, clover, and crop residues, cornstalks and straw, the very things this land needs, instead of burning them, as is commonly practiced. Ground limestone should be applied when needed to keep the soil sweet.

While this soil is one of the best in the state, yet the clay and humus contained in it give it the property of shrinkage and expansion to such a degree as to be somewhat objectionable at times. When the soil is wet, these constituents expand, and when the moisture evaporates or is used by crops, the soil shrinks. This results in the formation of cracks up to two inches or more in width, and extending with lessening width to a depth of a foot or more. These cracks allow the subsurface and subsoil to dry out rapidly. They sometimes "block out" the hills of corn, severing the roots and doing considerable damage to the crop. While cracking may not be prevented entirely in this type, yet good tilth with a soil mulch will do much toward that end.

Altho this soil is still moderately rich, its phosphorus content is not high, and it may well be increased to at least 2000 pounds per acre in the plowed soil, the nitrogen being maintained by means of legume crops and farm manure, as explained in the Appendix.

Brown-Gray Silt Loam on Tight Clay (428)

This type is found principally in the southern part of the county and represents a type of the transition zone between the lower and the middle Illinois glaciations. The type occurs in extensive areas in the counties south of Sangamon county. The small areas in Sangamon county usually represent some poorly drained places, altho in the northwest part of the county, in Township 17 North, and Ranges 5, 6, and 7 West, there are areas where the soil naturally seems to have a rather tight clay subsoil.

The type is generally flat, with poor drainage, principally due to the character of the subsoil. It occupies 2.6 square miles, or 1665 acres, only .3 percent of the total area.

The surface soil, 0 to 6⅔ inches, is a light brown or grayish brown silt loam, containing some fine sand and coarse silt which give it a peculiar mealy "feel." The organic-matter content varies from 2.2 to 3.5 percent, according to its relation to other types, being greater where it approaches brown silt loam (426) or black silt loam on clay (425.1) and less where it passes toward yellow-gray silt loam.

The subsurface is represented by a stratum from 10 to 12 inches thick. The color varies from a brown to a gray silt loam, or the upper part of this

stratum may be brown and the lower gray. It differs in physical composition from the surface in having less organic matter, the average amount being 1.3 percent.

The subsoil consists of a stratum of clay, beginning at from 16 to 18 inches beneath the surface and varying from 10 to 20 inches in thickness. It is frequently underlain by pervious silt.

Primarily this soil in this county needs good drainage. Lines of tile must be placed nearer each other than in brown silt loam, because of the almost impervious character of the subsoil. Care should be taken to increase the organic matter by proper rotation and turning under crop residues or farm manure. Where this is done, the phosphorus content also should be increased by liberal use of fine-ground rock phosphate. For the best results, limestone should also be applied. The initial application may well be from 3 to 5 tons per acre, and subsequent additions about 2 tons every four or five years.

Black Silt Loam on Clay (425.1)

This type comprises only 1.24 percent of the area of the county but covers a total area of 10.83 square miles, or 6,928 acres. It occurs mostly in small areas over the county, usually adjoining areas of black clay loam (420) or brown-gray silt loam on tight clay (428). As a general thing, with about the same topography as black clay loam (420), it does not permit of as good underdrainage, because of the fact that the subsoil is somewhat tight. This is especially true where the type approaches the brown-gray silt loam on tight clay (428).

The surface soil, 0 to 6⅔ inches, is a black silt loam, varying on the one hand toward a black clay loam, and on the other to a brown-silt loam. When thoroly drained, it is naturally granular and in good tilth, but the same precautions must be taken in regard to this type as with black clay loam.

The organic-matter content is about the same as that of the black clay loam, varying from 5.5 to 6.5 percent and averaging about 60 tons per acre in the surface soil.

The subsurface stratum varies from 8 to 14 inches in thickness, and in color from black or dark brown to a drab or yellowish drab, becoming lighter with depth. The proportion of clay increases somewhat with depth, and usually the lower part of this stratum is a clay. The subsoil resembles that of the black clay loam.

This soil type is moderately rich, but its productive power can be increased by means of phosphorus and fresh organic manures, both of which are necessary if permanent systems of soil maintenance are to be practiced. Limestone also should be applied, especially where the subsoil is devoid of that important material.

(b) UPLAND TIMBER SOILS

Yellow-Gray Silt Loam (434)

This type occurs in the outer timber belts along the Sangamon river and its tributaries, covering 11.93 percent of the county, or 103.85 square miles (66,460 acres). The topography is sufficiently rolling for good surface drainage without much tendency to wash if proper care is taken.

The surface soil, 0 to 6⅔ inches, is a gray to yellowish gray silt loam, incoherent and mealy but not granular. The amount of organic matter varies from 1.8 to 2.3 percent, or an average of 20 tons per acre.

The subsurface stratum varies from 3 to 10 inches in thickness, the greatest variation being due to topography. In color it is a gray, grayish yellow, or yellow silt loam, somewhat mealy but becoming more coherent and clayey with depth, with only .72 percent of organic matter.

The subsoil is a yellow, or grayish yellow mottled, clayey silt or silty clay, somewhat plastic when wet, but friable when only moist, and pervious to water. The type is quite variable, due to the fact that it grades into so many different types. There is frequently a transition zone between two types and this gives a variation in both.

In the management of this type one of the first things is the maintenance or increase of organic matter in order to give better tilth, to supply or liberate plant food, prevent "running together," and, in some of the more rolling phases, to prevent washing. Another essential is the application of ground limestone in order to grow clover, alfalfa, and other legumes more successfully. This soil is also deficient in phosphorus, and this must be supplied in any system of profitable, permanent improvement of this type. The chief difference physically between this soil and the common prairie is in the smaller amount of organic matter in the surface and subsurface of the timber lands, which, consequently, are also poorer in nitrogen and often somewhat poorer in phosphorus, because the nitrogen is contained only in the organic matter, while phosphorus is contained in both organic and mineral forms. Initial applications of 1 ton of fine-ground phosphate plowed under with clover or manure, and of 2 to 5 tons of limestone, may well be made, with subsequent applications of ½ ton of phosphate and 2 tons of limestone per acre every four or five years.

Yellow Silt Loam (435)

This type covers about 6.23 percent of the area of the county, equivalent to 54.23 square miles or 34,709 acres. It occurs on the inner timber belts along the streams as the hilly and badly eroded land, usually only in narrow, irregular strips with arms extending up the small streams. The topography is very rolling and so badly broken that it should not be cultivated as a rule, because of the danger of injury from washing.

The surface soil, 0 to 6⅔ inches, is a yellow or grayish yellow pulverulent, mealy silt loam. This varies a great deal, due to recent washing. In some places the real subsoil may be exposed.

The typical subsurface varies considerably with the amount of washing. In thickness it varies from 0 to 12 inches, the variation being due to the removal of the surface and part of the subsurface. The subsoil is a compact, yellow, clayey silt.

In the management of this type the most important thing is to prevent general surface washing and gullying. If it is cropped at all, a rotation should be practiced that will require a cultivated crop as little as possible and allow a great deal of pasture and meadow. If tilled, the land should be plowed deeply and contours should be followed as nearly as possible, both in plowing and planting. Furrows extending up and down the slopes should be avoided. Cultivation should be done in the same direction as plowing. Every means should be employed to maintain and increase the organic-matter content to help hold the soil and keep it in good physical condition so it will absorb a large amount of water and thus diminish the run-off. (See Circular 119.)

When this soil is to be prepared for seeding down, it may well be treated with five tons per acre of ground limestone, in order to encourage the growth of clover and thus to make possible the accumulation of nitrogen, the element in which this type is most deficient. As a rule it is not advisable to try to enrich this soil in phosphorus, because of the fact that erosion is sure to occur to some extent, and the phosphorus supply will thus be renewed from the subsoil.

One of the most profitable crops to grow on this land is alfalfa, and to get this well started requires liberal use of limestone, thoro inoculation, and a moderate application of farm manure. If the manure is not available, it is well to apply about 500 pounds per acre of acid phosphate, mix it with the soil, by disking if possible, and then plow it under, the 5 tons of limestone being applied after plowing and mixed with the surface soil in the preparation of the seed bed. The special purpose of this treatment is to give the alfalfa a quick start in order that it may grow rapidly and thus protect the soil from washing.

Light Gray Silt Loam on Tight Clay (432)

Only a comparatively small total area of this type is found in the county. It aggregates .42 percent, equivalent to 3.75 square miles or 2402 acres. The areas are generally small, distributed irregularly along the Sangamon river, South Fork, and Horse Creek. The larger areas occur in Town 15, Ranges 3 and 4 West. The topography is flat, with poor drainage, altho not swampy. These areas were usually protected from the prairie fires by streams or broken land on the southwest. This type is practically all cleared of the white oak, hickory, black jack, and post oak that formerly covered it.

The surface soil is a white or very light-gray silt loam, incoherent, friable and porous. Round iron concretions are usually present. The organic-matter content is low, being about 1.6 percent, or 16 tons per acre 6⅔ inches deep.

The subsurface is a light gray silt extending to a depth of 16 to 18 inches, becoming more clayey with depth and containing only .5 percent of organic matter.

The subsoil is a tight, compact, clayey silt, yellow with gray mottlings. Below 36 inches the subsoil is usually coarser and more pervious.

This soil is very deficient in organic matter and lacking in lime, and is necessarily in poor physical condition. The soil runs together badly and does not hold moisture well, owing to the strong capillarity in the surface and subsurface strata. In the management of this soil, ground limestone and rock phosphate should be added and the content of organic matter increased in every practical way. Deep-rooting crops, such as red, mammoth or sweet clover, would loosen the tight clay subsoil as well as supply the soil with organic matter and nitrogen. Crop residues should be plowed under, by all means, to bring the soil into better tilth. Where not well drained, alsike will grow better than red clover, and pasturing is one of the best uses of this land, altho it may well be liberally enriched in limestone and phosphorus before seeding down, and alsike and white clover should be included in the mixture of grass seed.

Yellow-Gray Sandy Loam (464)

This type occupies .53 percent of the county, or 4.64 square miles (2,971 acres), and is found near the larger streams, the sand having been derived from the bottom land and transported by the wind. It occurs mostly on the east and north sides of the bottom land, with an apparent exception where the upland on the south side of the Sangamon river juts out into the bottom land in Township 16 North, Ranges 4 and 5 West. These broad areas extend out far enough to catch the sand blown up by the westerly winds.

The topography varies to a considerable extent, in places resembling that ordinarily found in the upland, while in others it has a dune character.

The surface soil, 0 to 6⅔ inches, is a light brownish yellow to grayish-yellow sandy loam. The sand is mostly medium but mixed with some coarse and considerable fine sand.

The subsurface is a yellowish gray or yellow sandy loam but varies a great deal, in some places being only a silty material covered by a layer that constitutes the sandy loam, while in others this stratum runs into sand and continues partly or entirely thru the subsoil.

This soil is low in organic matter, the surface containing 1.3 percent, or 13 tons per acre. Care must be taken to use every means to increase the organic-matter content. This is especially necessary to provide nitrogen for the soil, and, secondarily, to liberate plant food and put the soil in better physical condition.

No field experiments have been conducted on this soil type; but from experiments on more sandy land at Green Valley in Tazewell county (see Bulletin 123), it is doubtful if the addition of phosphorus will prove profitable wherever the subsoil is very sandy, thus permitting a very deep feeding range for the plant roots. From 2 to 5 tons per acre of limestone should be applied, with renewed applications of 2 tons per acre every four or five years. Sufficient legume crops, crop residues, or farm manure should be plowed under to provide the nitrogen needed by the non-leguminous crops to be grown (see Appendix). This soil is especially well adapted to alfalfa when properly treated with limestone and well inoculated, farm manure being used to give the alfalfa a good start.

Yellow Sandy Loam (465)

This type covers an area of 4,845 square miles, or 3,102 acres, being .55 percent of the area of the county. It occurs in the same region as the yellow-gray sandy loam (464).

The topography is very rolling and hilly. Care must be taken to prevent washing, altho there is not the danger from this cause that there is in the case of silt loams.

The surface soil, 0 to 6⅔ inches, is a light brown to yellow sandy loam. All grades of sand are found, but medium sand predominates. This stratum contains only 1 percent of organic matter, or 10 tons per acre.

The subsurface varies from a yellow sandy loam to a sand, and this sand continues to forty inches. As a rule this land should be left in forest, but where cropped large use should be made of legumes. While the surface soil contains a small amount of limestone (probably in the form of light pieces of shells blown with the sand from the bottom lands), liberal use of ground limestone would be helpful for growing legumes, especially for alfalfa.

Dune Sand (481)

The sand dunes occupy part of the upland sandy tracts in various places, but usually only small isolated areas, the largest being not more than 80 acres.

The entire area occupied by the type is 1.43 square miles, or 914 acres, constituting only .15 percent of the county. Dune topography characterizes this type.

The surface is a light brown sand passing into a yellow sand that constitutes both the subsurface and subsoil. The organic-matter content is exceedingly low, being only .4 percent, or 4 tons per acre. This indicates a low nitrogen content, and every practical means should be taken to increase the organic matter for the purpose of furnishing nitrogen as well as to prevent blowing of soil.

Liberal use of limestone (preferably dolomite, because of the low magnesium content of this soil) is especially important for the improvement of this sand soil; and legumes should be the principal crops grown. While this soil is the lowest in phosphorus of all the types in the county, it is very doubtful if any form of phosphorus can be applied with profit. The soil is abnormal in physical character, being so open and porous that the feeding range afforded the plant roots is very great. The air easily penetrates such soil, so that oxidation and liberation of plant food occur at much greater depths than in heavier soils. Furthermore, the phosphorus is contained in both organic and mineral forms, and the mineral phosphorus may be associated with calcium and iron compounds not locked up in the sand grains.

Next to limestone and organic matter, the addition of kainit is to be recommended for the improvement of this sand soil, especially to get a good start with alfalfa, cowpeas, or other legumes. The kainit furnishes soluble salts, including potassium which, tho present in the sand in considerable amount, is chiefly locked up in the sand grains. (Any one interested in sand soil is advised to study Bulletin 123.)

(c) SWAMP AND BOTTOM-LAND SOILS

Deep Brown Silt Loam (1426)

The bottom-land soil is derived from material washed from the upland. It must therefore have some relation to the uplands. It differs in being more variable as to physical composition than any single upland type, and the brown color extends into it to greater depth. The bottoms along streams vary from a few rods to a mile or more in width. These lands occupy 77.65 square miles, equivalent to 49,696 acres, and constitute 8.93 percent of the entire area of the county. The topography is flat or with very slight undulations that represent old stream or overflow channels. Better drainage is needed in much of this area.

The surface soil, 0 to 6⅔ inches, is a brown silt loam containing from 3.5 to 5.3 percent of organic matter, the average being 4.4 percent, or 44 tons per acre. It is probably easier to maintain the organic matter in this type than in the upland because of the occasional overflow and the consequent deposition of material rich in this constituent. The physical composition of the soil varies from a clay loam to a sandy loam, but the areas of these extreme types, especially the latter, are so small and so changeable that it really

does not mean very much to show them on the map as the next flood may change their boundaries.

The subsurface is brown silt loam, becoming lighter with depth. It contains an average of 3.2 percent of organic matter.

The subsoil is a yellowish drab silt loam, varying in physical composition either to a clayey silt or to a sandy loam or even a sand in the lower subsoil.

The type is quite productive where proper drainage is secured; and as a rule no soil treatment is recommended except good farming. Even the systematic rotation of crops is not important where the land overflows occasionally, but where it is protected from overflow a rotation including legume crops should be practiced, and ultimately provision would need to be made for the enrichment of such protected land.

APPENDIX

A study of the soil map and the tabular statements concerning crop requirements, the plant-food content of the different soil types, and the actual results secured from definite field trials with different methods or systems of soil improvement, and a careful study of the discussion of general principles and of the descriptions of individual soil types, will furnish the most necessary and useful information for the practical improvement and permanent preservation of the productive power of every kind of soil on every farm in the county.

More complete information concerning the most extensive and important soil types in the great soil areas in all parts of Illinois is contained in Bulletin 123, "The Fertility of Illinois Soils," which contains a colored general survey soil map of the entire state.

Other publications of general interest are:

Bulletin No. 76, "Alfalfa on Illinois Soils"
Bulletin No. 94, "Nitrogen Bacteria and Legumes"
Bulletin No. 115, "Soil Improvement for the Worn Hill Lands of Illinois"
Bulletin No. 125, "Thirty Years of Crop Rotation on the Common Prairie Lands of Illinois"
Circular No. 110, "Ground Limestone for Acid Soils"
Circular No. 127, "Shall we use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils?"
Circular No. 129, "The Use of Commercial Fertilizers"
Circular No. 149, "Some Results of Scientific Soil Treatment" and "Methods and Results of Ten Years' Soil Investigation in Illinois"

NOTE.—Information as to where to obtain limestone, phosphate, bone meal, and potassium salts, methods of application, etc., will also be found in Circulars 110 and 149.

SOIL SURVEY METHODS

The detail soil survey of a county consists essentially of indicating on a map the location and extent of the different soil types; and, since the value of the survey depends upon its accuracy, every reasonable means is employed to make it trustworthy. To accomplish this object three things are essential: first, careful, well-trained men to do the work; second, an accurate base map upon which to show the results of their work: and, third, the means necessary to enable the men to place the soil-type boundaries, streams, etc., accurately upon the map.

The men selected for the work must be able to keep their location exactly and to recognize the different soil types, with their principal variations and limits, and they must show these upon the maps correctly. A definite system is employed in checking up this work. As an illustration, one soil expert will survey and map a strip 80 rods or 160 rods wide and any convenient length, while his associate will work independently on another strip adjoining this area, and, if the work is correctly done, the soil type boundaries will match up on the line between the two strips.

An accurate base map for field use is absolutely necessary for soil mapping. The base maps are made on a scale of one inch to the mile. The official data of the original or subsequent land survey are used as a basis in the construction of these maps, while the most trustworthy county map available is used in locating temporarily the streams, roads, and railroads. Since the best of these published maps have some inaccuracies, the location of every road, stream, and railroad must be verified by the soil surveyors, and cor-

rected if wrongly located. In order to make these verifications and corrections, each survey party is provided with an odometer for measuring distances, and a plane table for determining directions of roads, railroads, etc.

Each surveyor is provided with a base map of the proper scale, which is carried with him in the field; and the soil-type boundaries, additional streams, and necessary corrections are placed in their proper locations upon the map while the mapper is on the area. Each section, or square mile, is divided into 40-acre plots on the map, and the surveyor must inspect every ten acres and determine the type or types of soil composing it. The different types are indicated on the map by different colors, pencils being carried in the field for this purpose.

A small augur 40 inches long forms for each man an invaluable tool with which he can quickly secure samples of the different strata for inspection. An extension for making the augur 80 inches long is taken by each party, so that any peculiarity of the deeper subsoil layers may be studied. Each man carries a compass to aid in keeping directions. Distances along roads are measured by an odometer attached to the axle of the vehicle, while distances in the field off the roads are determined by pacing, an art in which the men become expert by practice. The soil boundaries can thus be located with as high a degree of accuracy as can be indicated by pencil on the scale of one inch to the mile.

SOIL CHARACTERISTICS

The unit in the soil survey is the soil type, and each type possesses more or less definite characteristics. The line of separation between adjoining types is usually distinct, but sometimes one type grades into another so gradually that it is very difficult to draw the line between them. In such exceptional cases, some slight variation in the location of soil-type boundaries is unavoidable.

Several factors must be taken into account in establishing soil types. These are (1) the geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial, or cumulose; (2) the topography, or lay of the land; (3) native vegetation, as forest or prairie grasses; (4) the structure, or the depth and character of the surface, subsurface, and subsoil; (5) the physical or mechanical composition of the different strata composing the soil, as the percentages of gravel, sand, silt, clay, and organic matter which they contain; (6) the texture, or porosity, granulation, friability, plasticity, etc.; (7) the color of the strata; (8) the natural drainage; (9) agricultural value, based upon its natural productiveness; (10) the ultimate chemical composition and reaction.

The common soil constituents are indicated in the following outline:

CONSTITUENTS OF SOILS

Soil Constituents	Organic Matter	Comprising undecomposed and partially decayed vegetable material	
	Inorganic Matter	Clay	.001 mm.* and less
		Silt	.001 mm. to .03 mm.
		Sand	.03 mm. to 1. mm.
		Gravel	1. mm. to 32 mm.
		Stones	32. mm. and over

*25 millimeters equal 1 inch.

Further discussion of these constituents is given in Circular 82.

GROUPS OF SOIL TYPES

The following gives the different general groups of soils:

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or silt.

Peaty loams—15 to 35 percent of organic matter mixed with much sand and silt and a little clay.

Mucks—15 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 25 percent of clay, usually mixed with much silt.

Clay loams—Soils with from 15 to 25 percent of clay, usually mixed with much silt and some sand.

Silt loams—Soils with more than 50 percent of silt and less than 15 percent of clay, mixed with some sand.

Loams—Soils with from 30 to 50 percent of sand mixed with much silt and a little clay.

Sandy loams—Soils with from 50 to 75 percent of sand.

Fine sandy loams—Soils with from 50 to 75 percent of fine sand mixed with much silt and little clay.

Sands—Soils with more than 75 percent of sand.

Gravelly loams—Soils with 15 to 50 percent of gravel with much sand and some silt.

Gravels—Soils with more than 50 percent of gravel.

Stony loams—Soils containing a considerable number of stones over one inch in diameter.

Rock outcrop—Usually ledges of rock having no agricultural value.

More or less organic matter is found in nearly all the above classes.

SUPPLY AND LIBERATION OF PLANT FOOD

The productive capacity of land in humid sections depends almost wholly upon the power of the soil to feed the crop; and this, in turn, depends both upon the stock of plant food contained in the soil and upon the rate at which this is liberated, or rendered soluble and available for use in plant growth. Protection from weeds, insects, and fungous diseases, tho exceedingly important, is not a positive but a negative factor in crop production.

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but the rate of liberation is governed by many factors, some of which may be controlled by the farmer, while others are largely beyond his control. Chief among the important controllable factors which influence the liberation of plant food are limestone and decaying organic matter, which may be added to the soil by direct application of ground limestone and farm manure. Organic matter may be supplied also by green-manure crops and crop residues, such as clover, cowpeas, straw, and cornstalks. The rate of decay of organic matter depends largely upon its age and origin, and it may be hastened by tillage. The chemical analysis shows correctly the total organic carbon, which represents, as a rule, but little more than half the organic matter; so that 20,000 pounds of organic carbon in the plowed soil of an acre correspond to nearly

20 tons of organic matter. But this organic matter consists largely of the old organic residues that have accumulated during the past centuries because they were resistant to decay, and 2 tons of clover or cowpeas plowed under may have greater power to liberate plant food than the 20 tons of old, inactive organic matter. The recent history of the individual farm or field must be depended upon for information concerning recent additions of active organic matter, whether in applications of farm manure, in legume crops, or in grass-root sods of old pastures.

Probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that with the normal rainfall of Illinois the productive power of the land depends primarily upon the stock of plant food contained in the soil and upon the rate at which it is liberated, just as the success of the merchant depends primarily upon his stock of goods and the rapidity of sales. In both cases the stock of any commodity must be increased or renewed whenever the supply of such commodity becomes so depleted as to limit the success of the business, whether on the farm or in the store.

As the organic matter decays, certain decomposition products are formed, including much carbonic acid, some nitric acid, and various organic acids, and these have power to act upon the soil and dissolve the essential mineral plant foods, thus furnishing soluble phosphates, nitrates, and other salts of potassium, magnesium, calcium, etc., for the use of the growing crop.

As already explained, fresh organic matter decomposes much more rapidly than the old humus, which represents the organic residues most resistant to decay and which consequently has accumulated in the soil during the past centuries. The decay of this old humus can be hastened both by tillage, which maintains a porous condition and thus permits the oxygen of the air to enter the soil more freely and to effect the more rapid oxidation of the organic matter, and also by incorporating with the old, resistant residues some fresh organic matter, such as farm manure, clover roots, etc., which decay rapidly and thus furnish or liberate organic matter and inorganic food for bacteria, the bacteria, under such favorable conditions, appearing to have power to attack and decompose the old humus. It is probably for this reason that peat, a very inactive and inefficient fertilizer when used by itself, becomes much more effective when incorporated with fresh farm manure; so that, when used together, two tons of the mixture may be worth as much as two tons of manure, but if applied separately, the peat has little value. Bacterial action is also promoted by the presence of limestone.

The condition of the organic matter of the soil is indicated more or less definitely by the ratio of carbon to nitrogen. As an average, the fresh organic matter incorporated with soils contains about twenty times as much carbon as nitrogen, but the carbohydrates ferment and decompose much more rapidly than the nitrogenous matter; and the old resistant organic residues, such as are found in normal subsoils, commonly contain only five or six times as much carbon as nitrogen. Soils of normal physical composition, such as loam, clay loam, silt loam, and fine sandy loam, when in good productive

condition, contain about twelve to fourteen times as much carbon as nitrogen in the surface soil; while in old, worn soils that are greatly in need of fresh, active, organic manures, the ratio is narrower, sometimes falling below ten of carbon to one of nitrogen. (Except in newly made alluvial soils, the ratio is usually narrower in the subsurface and subsoil than in the surface stratum.)

It should be kept in mind that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all agricultural plants, only one (hydrogen) from water, and seven from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes), in case the amount liberated from the soil is insufficient; but even these plants (which include only the clovers, peas, beans, and vetches, among our common agricultural plants) secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron and sulfur), and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Plants are made of plant-food elements in just the same sense that a building is made of wood and iron, brick, stone, and mortar. Without materials, nothing material can be made. The normal temperature, sunshine, rainfall, and length of season in central Illinois are sufficient to produce 50 bushels of wheat per acre, 100 bushels of corn, 100 bushels of oats, and 4 tons of clover hay; and, where the land is properly drained and properly tilled, such crops would frequently be secured *if the plant foods were present in sufficient amounts and liberated at a sufficiently rapid rate to meet the absolute needs of the crops.*

CROP REQUIREMENTS

The accompanying table shows the requirements of such crops for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally in sufficient abundance compared with the amounts needed by plants, so that they are not known ever to limit the yield of general farm crops grown under normal conditions).

TABLE A.—PLANT FOOD IN WHEAT, CORN, OATS, AND CLOVER

Produce: Kind	Produce: Amount	Nitrogen, pounds	Phosphorus, pounds	Potassium, pounds	Magnesium, pounds	Calcium, pounds
Wheat, grain	50 bu.	71	12	13	4	1
Wheat straw	2½ tons	25	4	45	4	10
Corn, grain	100 bu.	100	17	19	7	1
Corn stover	3 tons	48	6	52	10	21
Corn cobs	½ ton	2		2		
Oats, grain	100 bu.	66	11	16	4	2
Oat straw	2½ tons	31	5	52	7	15
Clover seed	4 bu.	7	2	3	1	1
Clover hay	4 tons	160	20	120	31	117
Total in grain and seed		244*	42	51	16	4
Total in four crops		510*	77	322	68	168

*These amounts include the nitrogen contained in the clover seed or hay, which, however, may be secured from the air.

To be sure, these are large yields, but shall we try to make possible the production of yields only half or a quarter as large as these, or shall we set as our ideal this higher mark, and then approach it as nearly as possible with profit? Among the four crops, corn is the largest, with a total yield of more than six tons per acre; and yet the 100-bushel crop of corn is often produced on rich pieces of land in good seasons. In very practical and profitable systems of farming, the Illinois Experiment Station has produced, as an average of the six years 1905 to 1910, a yield of 87 bushels of corn per acre in grain farming (with limestone and phosphorus applied, and with crop residues and legume crops turned under), and 90 bushels per acre in live-stock farming (with limestone, phosphorus, and manure).

The importance of maintaining a rich surface soil cannot be too strongly emphasized. It is well illustrated by data from the Rothamsted Experiment Station, the oldest in the world. Thus on Broadbalk field, where wheat has been grown since 1844, the average yields for the ten years 1892 to 1901 were 12.3 bushels per acre on Plot 3 (unfertilized) and 31.8 bushels on Plot 7 (well fertilized), but the amounts of both nitrogen and phosphorus in the subsoil (9 to 27 inches) were distinctly greater in Plot 3 than in Plot 7, thus showing that the higher yields from Plot 7 were due to the fact that the plowed soil had been enriched. In 1893 Plot 7 contained per acre in the surface soil (0 to 9 inches) about 600 pounds more nitrogen and 900 pounds more phosphorus than Plot 3. Even a rich subsoil has little value if it lies beneath a worn-out surface.

METHODS OF LIBERATING PLANT FOOD

Limestone and decaying organic matter are the principal materials the farmer can utilize most profitably to bring about the liberation of plant food.

The limestone corrects the acidity of the soil and thus encourages the development not only of the nitrogen-gathering bacteria which live in the nodules on the roots of clover, cowpeas, and other legumes, but also the nitrifying bacteria, which have power to transform the insoluble and unavailable organic nitrogen into soluble and available nitrate nitrogen.

At the same time, the products of this decomposition have power to dissolve the minerals contained in the soil, such as potassium and magnesium, and also to dissolve the insoluble phosphate and limestone which may be applied in low-priced forms.

Tillage, or cultivation, also hastens the liberation of plant food by permitting the air to enter the soil and burn out the organic matter; but it should never be forgotten that tillage is wholly destructive, that it adds nothing whatever to the soil, but always leaves the soil poorer. Tillage should be practiced so far as is necessary to prepare a suitable seed-bed for root development and also for the purpose of killing weeds, but more than this is unnecessary and unprofitable in seasons of normal rainfall; and it is much better actually to enrich the soil by proper applications or additions, including limestone and organic matter (both of which have power to improve the physical condition as well as to liberate plant food) than merely to hasten soil depletion by means of excessive cultivation.

PERMANENT SOIL IMPROVEMENT

The best and most profitable methods for the permanent improvement of the common soils of Illinois are as follows:

(1) If the soil is acid, apply at least two tons per acre of ground limestone, preferably at times magnesian limestone ($CaCO_3MgCO_3$), which contains both calcium and magnesium and has slightly greater power to correct soil acidity, ton for ton, than the ordinary calcium limestone ($CaCO_3$); and continue to apply about two tons per acre of ground limestone every four or five years. On strongly acid soils, or in preparing the land for alfalfa, five tons per acre of ground limestone may well be used for the first application.

(2) Adopt a good rotation of crops, including a liberal use of legumes, and increase the organic matter of the soil either by plowing under the legume crops and other crop residues (straw and corn stalks), or by using for feed and bedding practically all the crops raised and returning the manure to the land with the least possible loss. No one can say in advance what will prove to be the best rotation of crops, because of variation in farms and farmers, and in prices for produce, but the following are suggested to serve as models or outlines:

First year, corn (with some winter legume, such as red clover, alsike, sweet clover, or alfalfa, or a mixture, seeded on part of the field at the last cultivation).
Second year, oats or barley or wheat (fall or spring) on one part and cowpeas or soybeans where the winter catch crop is plowed down late in the spring.
Third year, wheat or oats (with clover or clover and grass).
Fourth year, clover or clover and grass.
Fifth year, wheat and clover or grass and clover.
Sixth year, clover or clover and grass.

Of course there should be as many fields as there are years in the rotation. In grain farming, with wheat grown the third and fifth years, most of the coarse products should be returned to the soil, and the clover may be clipped and left on the land (only the clover seed being sold the fourth and sixth years); or, in live-stock farming, the field may be used three years for timothy and clover pasture and meadow if desired. The system may be reduced to a five-year rotation by cutting out either the second or the sixth year, and to a four-year system by omitting the fifth and sixth years.

With two years of corn, followed by oats with clover-seeding the third year, and by clover the fourth year, all produce can be used for feed and bedding if other land is available for permanent pasture. Alfalfa may be grown on a fifth field for four or eight years, which is to be alternated with one of the four; or the alfalfa may be moved every five years, and thus rotated over all five fields every twenty-five years.

Other four-year rotations more suitable for grain farming are:

Wheat (and clover), corn, oats, and clover, or corn (and clover), cowpeas, wheat, and clover. (Alfalfa may be grown on a fifth field and rotated every five years, the hay being sold.)

Good three-year rotations are:

Corn, oats, and clover; corn, wheat, and clover; or wheat (and clover), corn (and clover), and cowpeas, in which two cover crops and one regular crop of legumes are grown in three years.

A five-year rotation of (1) corn (and clover), (2) cowpeas, (3) wheat, (4) clover, and (5) wheat (and clover) allows legumes to be seeded four times, and alfalfa may be grown on a sixth field for five or six years in the combination rotation, alternating between two fields every five years, or rotating over all fields if moved every six years.

To avoid clover sickness it may sometimes be necessary to substitute red clover or alsike for the other in about every third rotation, and at the same

time to discontinue their use in the cover-crop mixture. If the corn crop is not too rank, cowpeas or soybeans may also be used as a cover crop (seeded at the last cultivation) in the southern part of the state, and, if necessary to avoid disease, these may well alternate in successive rotations.

For easy figuring it may well be kept in mind that the following amounts of nitrogen are required for the produce named:

1 bushel of oats (grain and straw) requires 1 pound of nitrogen.
1 bushel of corn (grain and stalks) requires 1½ pounds of nitrogen.
1 bushel of wheat (grain and straw) requires 2 pounds of nitrogen.
1 ton of timothy requires 24 pounds of nitrogen.
1 ton of clover contains 40 pounds of nitrogen.
1 ton of cowpeas contains 43 pounds of nitrogen.
1 ton of average manure contains 10 pounds of nitrogen.

The roots of clover contain about half as much nitrogen as the tops, and the roots of cowpeas contain about one-tenth as much as the tops.

Soils of moderate productive power will furnish as much nitrogen to clover (and two or three times as much to cowpeas) as will be left in the roots and stubble. For grain crops, such as wheat, corn, and oats, about two-thirds of the nitrogen is contained in the grain and one-third in the straw or stalks. (See also discussion of "The Potassium Problem," on pages below.)

(3) On all lands deficient in phosphorus (except on those susceptible to serious erosion by surface washing or gullying) apply that element in considerably larger amounts than are required to meet the actual needs of the crops desired to be produced. The abundant information thus far secured shows positively that fine-ground natural rock phosphate can be used successfully and very profitably, and clearly indicates that this material will be the most economical form of phosphorus to use in all ordinary systems of permanent, profitable soil improvement. The first application may well be one ton per acre, and subsequently about one-half ton per acre every four or five years should be applied, at least until the phosphorus content of the plowed soil reaches 2,000 pounds per acre, which may require a total application of from three to five or six tons per acre of raw phosphate containing 12½ percent of the element phosphorus.

Steamed bone meal and even acid phosphate may be used in emergencies, but it should always be kept in mind that phosphorus delivered in Illinois costs about 3 cents a pound in raw phosphate (direct from the mine in carload lots), but 10 cents a pound in steamed bone meal, and about 12 cents a pound in acid phosphate, both of which cost too much per ton to permit their common purchase by farmers in carload lots, which is not the case with limestone or raw phosphate.

Phosphorus once applied to the soil remains in it until removed in crops, unless carried away mechanically by soil erosion. (The loss by leaching is only about 1½ pounds per acre per annum, so that more than 150 years would be required to leach away the phosphorus applied in one ton of raw phosphate.)

The phosphate and limestone may be applied at any time during the rotation, but a good method is to apply the limestone after plowing and work it into the surface soil in preparing the seed bed for wheat, oats, rye, or barley, where clover is to be seeded; while phosphate is best plowed under with farm manure, clover, or other green manures, which serve to liberate the phosphorus.

(4) Until the supply of decaying organic matter has been made adequate, on the poorer types of upland timber and gray prairie soils some temporary benefit may be derived from the use of a soluble salt or mixture of salts, such as kainit, which contains both potassium and magnesium in soluble form and also some common salt (sodium chlorid). About 600 pounds per acre of kainit applied and turned under with the raw phosphate will help to dissolve the phosphorus as well as to furnish available potassium and magnesium, and for a few years such use of kainit will no doubt be profitable on lands deficient in organic matter, but the evidence thus far secured indicates that its use is not absolutely necessary and that it will not be profitable after adequate provision is made for decaying organic matter, since this will necessitate returning to the soil either all produce except the grain (in grain farming) or the manure produced in live-stock farming. (Where hay or straw is sold, manure should be bought.)

On soils which are subject to surface washings, including especially the yellow silt loam of the upland timber area, and to some extent the yellow-gray silt loam, and other more rolling areas, the supply of minerals in the subsurface and subsoil (which gradually renew the surface soil) tends to provide for a low-grade system of permanent agriculture if some use is made of legume plants, as in long rotations with much pasture, because both the minerals and nitrogen are thus provided in some amount almost permanently; but where such lands are farmed under such a system, not more than two or three grain crops should be grown during a period of ten or twelve years, the land being kept in pasture most of the time; and where the soil is acid a liberal use of limestone, as top dressings if necessary, and occasional reseeding with clovers will benefit both the pasture and indirectly the grain crops.

ADVANTAGE OF CROP ROTATION AND PERMANENT SYSTEMS

It should be noted that clover is not likely to be well infected with the clover bacteria during the first rotation on a given farm or field where it has not been grown before within recent years; but even a partial stand of clover the first time will probably provide a thousand times as many bacteria for the next clover crop as one could afford to apply in artificial inoculation, for a single root-tubercle may contain a million bacteria developed from one during the season's growth.

This is only one of several advantages of the second course of the rotation over the first course. Thus the mere practice of crop rotation is an advantage, especially in helping to rid the land of insects and foul grass and weeds. The deep-rooting clover crop is an advantage to subsequent crops because of that characteristic. The larger applications of organic manures (made possible by the larger crops) are a great advantage; and in systems of permanent soil improvement, such as are here advised and illustrated, more limestone and more phosphorus are provided than are needed for the meager or moderate crops produced during the first rotation, and consequently the crops in the second rotation have the advantage of such accumulated residues (well incorporated with the plowed soil) in addition to the regular applications made during the second rotation.

This means that these systems tend positively toward the making of richer lands. The ultimate analyses recorded in the tables give the absolute invoice of these Illinois soils. They show that most of them are positively deficient only in limestone, phosphorus, and nitrogenous organic matter: and

the accumulated information from careful and long-continued investigations in different parts of the United States clearly establishes the fact that in general farming these essentials can be supplied with greatest economy and profit by the use of ground natural limestone, very finely ground natural rock phosphate, and legume crops to be plowed under directly or in farm manure. On normal soils no other applications are absolutely necessary, but, as already explained, the addition of some soluble salt in the beginning of a system of improvement on some of these soils produces temporary benefit, and if some inexpensive salt, such as kainit, is used, it may produce sufficient increase to more than pay the added cost.

THE POTASSIUM PROBLEM

As reported in Illinois Bulletin 123, where wheat has been grown every year for more than half a century at Rothamsted, England, exactly the same increase was produced (5.6 bushels per acre), as an average of the first 24 years, whether potassium, magnesium, or sodium was applied, the rate of application per annum being 200 pounds of potassium sulfate and molecular equivalents of magnesium sulfate and sodium sulfate. As an average of 60 years (1852 to 1911), the yield of wheat has been 12.7 bushels on untreated land, 23.3 bushels where 86 pounds of nitrogen and 29 pounds of phosphorus per acre per annum were applied; and, as further additions, 85 pounds of potassium raised the yield to 31.3 bushels; 52 pounds of magnesium raised it to 29.2 bushels; and 50 pounds of sodium raised it to 29.5 bushels. Where potassium was applied, the average wheat crop removed 40 pounds of that element in the grain and straw, or three times as much as would be removed in the grain only for such crops as are suggested in Table A. The Rothamsted soil contained an abundance of limestone, but no organic matter was provided except the little in the stubble and roots of the wheat plants.

On another field at Rothamsted the average yield of barley for 60 years (1852 to 1911) has been 14.2 bushels on untreated land, 38.1 bushels where 43 pounds of nitrogen and 29 pounds of phosphorus have been applied per acre per annum; while the further addition of 85 pounds of potassium, 19 pounds of magnesium, and 14 pounds of sodium (all in sulfates) raised the average yield to 41.5 bushels, but, where only 70 pounds of sodium were applied in addition to the nitrogen and phosphorus, the average has been 43.0 bushels. Thus, as an average of 60 years, the use of sodium produced 1.8 bushels less wheat and 1.5 bushels more barley than the use of potassium, with both grain and straw removed and no organic manures returned.

In recent years the effect of potassium is becoming much more marked than that of sodium or magnesium, on the wheat crop; but this must be expected to occur in time where no potassium is returned in straw or manure, and no provision made for liberating potassium from the supply still remaining in the soil. If more than three-fourths of the potassium removed were returned in the straw (see Table A), and if the decomposition products of the straw have power to liberate additional amounts of potassium from the soil, the necessity of purchasing potassium in a good system of farming on such land is very remote.

While about half the potassium, nitrogen, and organic matter, and about one-fourth the phosphorus contained in manure will be lost by three or four months' exposure in the ordinary pile in the barn yard, there

is practically no loss if plenty of absorbent bedding is used on cement floors, and if the manure is hauled to the field and spread within a day or two after it is produced. Again, while the animals destroy two-thirds of the organic matter and retain one-fourth of the nitrogen and phosphorus in average live-stock farming, they retain less than one-tenth of the potassium, from the food consumed; so that the actual loss of potassium in the products sold from the farm, either in grain farming or in live-stock farming, is wholly negligible on land containing 25,000 pounds or more of potassium in the surface 6⅔ inches.

The removal of one inch of soil per century by surface washing (which is likely to occur wherever there is satisfactory surface drainage and frequent cultivation) would permanently maintain the potassium in grain farming by renewal from the subsoil, provided one-third of the potassium is removed by cropping before the soil is carried away.

From all of these facts it will be seen that the potassium problem is not one of addition but of liberation; and the Rothamsted records show that for many years other soluble salts have practically the same power as potassium to increase crop yields in the absence of sufficient decaying organic matter. Whether this action relates to supplying or liberating potassium for its own sake, or to the power of the soluble salt to increase the availability of phosphorus or other elements, is not known, but where much potassium is removed, as in the entire crops at Rothamsted, with no return of organic residues, probably the soluble salt functions in both ways.

As an average of 112 separate tests conducted in 1907, 1908, 1909, and 1910 on the Fairfield experiment field, an application of 200 pounds of potassium sulfate, containing 85 pounds of potassium and costing $5.10, increased the yield of corn by 9.3 bushels per acre; while 600 pounds of kainit, containing only 60 pounds of potassium and costing $4.00, gave an increase of 10.7 bushels. Thus, at 40 cents a bushel for corn, the kainit has paid for itself; but these results, like those at Rothamsted, were secured where no adequate provision had been made for decaying organic matter.

Additional experiments at Fairfield include an equally complete test with potassium sulfate and kainit on land to which 8 tons per acre of farm manure had been applied. As an average of 112 tests with each material, the 200 pounds of potassium sulfate increased the yield of corn by 1.7 bushels, while the 600 pounds of kainit also gave an increase of 1.7 bushels. Thus, where organic manure was supplied, very little effect was produced by the addition of either potassium sulfate or kainit; in part perhaps because the potassium removed in the crops is mostly returned in the manure if properly cared for; and perhaps in larger part because the decaying organic matter helps to liberate and hold in solution other plant-food elements, especially phosphorus.

In laboratory experiments at the Illinois Experiment Station, it has been shown that potassium salts and most other soluble salts increase the solubility of the phosphorus in soil and in rock phosphate as determined by chemical analysis; also that the addition of glucose with rock phosphate in pot-culture experiments increases the availability of the phosphorus, as measured by plant growth, altho the glucose consists only of carbon, hydrogen, and oxygen, and thus contains no plant food of value.

If we remember that, as an average, live stock destroy two-thirds of the organic matter of the food consumed, it is easy to determine from Table A

that more organic matter will be supplied in a proper grain system than in a strictly live-stock system; and the evidence thus far secured from older experiments at the University and at other places in the state indicates that if the corn stalks, straw, clover, etc., are incorporated with the soil as soon as practicable after they are produced (which can usually be done in the late fall or early spring), there is little or no difficulty in securing sufficient decomposition in our humid climate to avoid serious interference with the capillary movement of the soil moisture, a common danger from plowing under too much coarse manure of any kind in the late spring of a dry year.

If, however, the entire produce of the land is sold from the farm, as in hay farming, or when both grain and straw are sold, of course the draft on potassium will then be so great that in time it must be renewed by some sort of application. As a rule, such farmers ought to secure manure from town, since they furnish the bulk of the material out of which manure is produced.

CALCIUM AND MAGNESIUM

When measured by the actual crop requirements for plant food, magnesium and calcium are more limited in some Illinois soils than potassium. But with these elements we must also consider the loss by leaching. As an average of 90 analyses* of Illinois well-waters drawn chiefly from glacial sands, gravels, or till, 3 million pounds of water (about the average annual drainage per acre for Illinois) contained 11 pounds of potassium, 130 of magnesium, and 330 of calcium. These figures are very significant, and it may be stated that if the plowed soil is well supplied with the carbonates of magnesium and calcium, then a very considerable proportion of these amounts will be leached from that stratum. Thus the loss of calcium from the plowed soil of an acre at Rothamsted, England, where the soil contains plenty of limestone, has averaged more than 300 pounds a year as determined by analyzing the soil in 1865 and again in 1905. And practically the same amount of calcium was found by analyzing the Rothamsted drainage waters.

Common limestone, which is calcium carbonate ($CaCO_3$), contains, when pure, 40 percent of calcium, so that 800 pounds of limestone are equivalent to 320 pounds of calcium. Where 10 tons per acre of ground limestone were applied at Edgewood, Illinois, the average annual loss during the next ten years amounted to 790 pounds per acre. The definite data from careful investigations seems to be ample to justify the conclusion that where limestone is needed at least 2 tons per acre should be applied every 4 or 5 years.

It is of interest to note that thirty crops of clover of four tons each would require 3,510 pounds of calcium, while the most common prairie land of southern Illinois contains only 3,420 pounds of total calcium in the plowed soil of an acre. (See Soil Report No. 1.) Thus limestone has a positive value on some soils for the plant food which it supplies, in addition to its value in correcting soil acidity and in improving the physical condition of the soil. Ordinary limestone (abundant in the southern and western parts of the state) contains nearly 800 pounds of calcium per ton; while a good grade of dolomitic limestone (the more common limestone of northern Illinois) contains about 400 pounds of calcium and 300 pounds of magnesium per ton. Both of these elements are furnished in readily available form in ground dolomitic limestone.

*Reported by Doctor Bartow and associates, of the Illinois State Water Survey.

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

SOIL REPORT NO. 5

LA SALLE COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER,
J. H. PETTIT, and J. E. READHIMER

URBANA, ILLINOIS, JULY, 1913

State Advisory Committee on Soil Investigations

Ralph Allen, Delavan
F. I. Mann, Gilman
A. N. Abbott, Morrison
J. P. Mason, Elgin
C. V. Gregory, 538 S. Clark St., Chicago.

Agricultural Experiment Station Staff on Soil Investigations

Eugene Davenport, Director
Cyril G. Hopkins, Chief in Agronomy and Chemistry

Soil Survey—

J. G. Mosier, Chief
A. F. Gustafson, Associate
S. V. Holt, Associate
H. W. Stewart, Associate
H. C. Wheeler, Associate
F. A. Fisher, Assistant
F. M. W. Wascher, Assistant
R. W. Dickenson, Assistant
John Woodard, Assistant

Soil Analysis

J. H. Pettit, Chief
E. Van Alstine, Associate
J. P. Aumer, Associate
W. H. Sachs, First Assistant
Gertrude Niederman, Assistant
W. R. Leighty, Assistant
Oran Keller, Assistant
L. R. Binding, Assistant

Soil Biology

A. L. Whiting, First Assistant

Soil Experiment Fields—

J. E. Readhimer, Superintendent
Wm. G. Eckhardt,[1] Associate
O. S. Fisher, Associate
J. E. Whitchurch, Associate
E. E. Hoskins, Associate
F. C. Bauer, First Assistant
F. W. Garrett, Assistant

Soils Extension—

C. C. Logan, Associate

[1]On leave.

LA SALLE COUNTY SOILS

BY CYRIL G. HOPKINS, J. G. MOSIER, J. H. PETTIT, AND J. E. READHIMER

INTRODUCTION

About two-thirds of Illinois lies in the corn belt, where most of the prairie lands are black or dark brown in color. In the southern third of the state, the prairie soils are largely of a gray color. This region is better known as the wheat belt, altho wheat is often grown in the corn belt and corn is also a common crop in the wheat belt.

Moultrie county, representing the corn belt; Clay county, which is fairly representative of the wheat belt; and Hardin county, which is taken to represent the unglaciated area of the extreme southern part of the state, were selected for the first Illinois Soil Reports by counties. While these three county soil reports were sent to the Station's entire mailing list within the state, Sangamon, La Salle, and other subsequent reports are sent only to the residents of the county concerned and to any one else upon request.

Each county report is intended to be as nearly complete in itself as it is practicable to make it, and, even at the expense of some repetition, each will contain a general discussion of important fundamental principles to help the farmer and landowner to understand the meaning of the soil fertility invoice for the lands in which he is interested. In Soil Report No. 1, "Clay County Soils," this discussion serves in part as an introduction, while in this and other reports it will be found in the Appendix, but if necessary it should be read and studied in advance of the report proper.

La Salle county is located in the north-central part of the early Wisconsin glaciation. The soils of the county are divided into five classes as follows:

(1) Upland prairie soils, rich in organic matter. These were originally covered with wild prairie grasses, the partially decayed roots of which have been the source of the organic matter. The flat prairie land contains the higher amount of this constituent because it was largely preserved from decay by the presence of water.

(2) Upland timber soils, including those zones along stream courses over which forests once extended. The timber land contains much less organic matter because the large roots of dead trees and the surface layer of leaves, twigs, and fallen trees were burned by forest fires or suffered almost complete decay.

(3) Terrace soils, or second bottom land, representing the soils formed on fills of either silt or gravel or the flood plain of a stream when it flowed at a higher level than at present.

(4) Swamp and bottom lands, which include the lands that overflow along streams and a few small areas of swamps on the upland.

(5) Residual soils, formed by the decomposition of rocks in place. The entire area of this class is only 2½ square miles.

The general topography of the county is undulating or slightly rolling. There are, however, some very flat areas; also belts of very rolling or hilly land along the larger streams, and considerable areas of terraces and bottom lands. The difference in topography is due mainly to two causes—glacial action and stream erosion. Like most of the state, this county was covered by a glacial ice sheet during what is known as the glacial period. During this time, snow and ice accumulated in the vicinity of Hudson Bay to such an amount that it flowed southward until a point was reached where the ice melted as rapidly as it advanced.

In moving across the country, the ice gathered up all sorts and sizes of earthy material, including pebbles, boulders, and even large masses of rock. Many of these were carried for hundreds of miles and rubbed against the surface rocks or against each other until ground into powder. When the limit of advance was reached, where the ice largely melted, all of this material would accumulate in a broad, undulating ridge, or moraine. When the ice melted away more rapidy than it advanced, the terminus of the glacier would recede and leave a moraine of boulder clay to mark the outer limit of the ice sheet.

The ice made many advances, and with each advance a terminal moraine was formed. This has left a system of terminal moraines (irregularly concentric with Lake Michigan) having generally a steep outer slope while the inner slope is vertically much less but longer and more gradual. The intermorainal tracts are occupied chiefly by the broad areas of level or undulating prairies.

The material transported by the glacier varied with the character of the rocks over which it passed. Granites, limestones, sandstones, shales, etc., were mixed and ground up together. This mixture of all kinds of boulders, gravel, sand, silt, and clay is called boulder clay, till, glacial draft, or simply drift. The grinding and denuding power of glaciers is enormous. A mass of ice 100 feet thick exerts a pressure of 40 pounds per square inch, and this ice sheet may have been thousands of feet in thickness.

The materials pushed along in this mass of ice, especially the boulders and pebbles, became powerful agents for grinding and wearing away the surface over which the ice passed. Ridges and hills were rubbed down and valleys filled, and the surface features changed entirely.

A deposit of boulder clay covered the entire upland of the county to a depth varying from 5 to 300 feet, with an average of about 100 feet; but this was later covered by a deposit of loess, as hereinafter explained.

Physiography

The altitude of La Salle county varies from 430 feet in the Illinois-river valley to 930 feet on the Bloomington moraine north of Mendota. Other high altitudes are in the southwest and southeast parts of the county, but about four-fifths of the entire county is less than 700 feet above sea level.

The valley of the Illinois river is from 200 to 300 feet below the general upland. This has permitted considerable erosion, and as a result the land adjacent to the bottom land of the larger streams is cut up into hills and valleys unsuited for ordinary agriculture. Before the land was put un-

der cultivation, forests had extended their way up the smaller streams and were slowly invading the adjoining prairies. The influence of the prevailing southwesterly wind may be seen in the greater extension of the forests to the north and east of the protecting streams, as shown in the soil types.

The early Wisconsin glacier is responsible for three moraines: one, a very distinct ridge, known as the Bloomington moraine, crosses the northwest corner of the county; another, less distinct, crosses the Illinois river at Utica and extends northeast and southeast from this point, the north arm terminating near Earlville and the south arm coalescing with another moraine in the southeast part of the county; the third, the Marseilles moraine, enters the county northeast of the town of Marseilles, extends southwest across the Illinois river and thence southward into Livingston county. Between these moraines are broad inter-morainal areas of gently rolling prairie land with many flat areas of poor drainage. The old drainage system was almost completely filled and destroyed by the glacial drift, but gradually a new system has been developed. The large streams have eroded valleys from 5 to 250 feet deep and in some cases have formed narrow flood plains. Small streams tributary to the large ones have formed valleys extending back from the bluffs, and along the larger streams there gradually has been formed a zone of broken to hilly land. The time elapsed since the glaciers, however, has not been sufficient to develop a complete natural drainage system for the county, and it therefore has been necessary to supplement the work of nature by artificial means, with the result that the entire upland of the county is now well drained. The Illinois river flowing thru the central part of the county from east to west furnishes a good outlet for the half dozen streams with their tributaries that drain the county.

Bench lands, or terraces, are found along the larger streams; namely, the Illinois, Fox, and Vermilion rivers, and Indian creek,—a fact which indicates that these streams formerly carried a larger volume of both sediment and water.

Topography and Formation

The topography of the bottom lands is modified somewhat by deformation. All limestones, sandstones, and shales were formed in large bodies of water, from material deposited in almost horizontal strata. Usually when this became dry land, the strata still remained horizontal. Sometimes long fissures would occur in these rocks and one side would push up or drop down so that the rocks on the opposite sides would not correspond. This formation is called a *fault*. Sometimes the strata of rock would be pushed up into arches, or even into folds, as the earth contracted, forming what are known as *anticlines*.

The La Salle anticline (arch) has a steep slope to the southwest, while the slope to the northeast is more gradual. This anticline enters the state from Wisconsin near Winslow (Stephenson county), passes near Grand Detour, La Salle, Tuscola, and Bridgeport (Lawrence county), and is responsible for the oil fields (which lie beneath the arch) in the southeastern part of the state. This anticline does not seem to affect the topography of the upland in La Salle county, but in the valley of the Illinois river its effect is very striking. West of the anticline the bottom land all overflows, and is what is commonly called *first bottom;* while east of the anticline the overflow land is of small extent and in many places is either entirely absent or is replaced by second bottom, or bench lands. Most of these lands are un-

derlain by rock at no great depth; in fact, the rock frequently comes too near to the surface to permit tillage. The underlying rock is mostly sandstone. In some cases it even gives rise to a residual soil type (No. 060.5), and it also modifies the more common brown sandy loam on rock (No. 1560.5).

SOIL MATERIAL AND SOIL TYPES

The early Wisconsin glacier covered La Salle county and left a thick mantle of drift, completely burying the old soil that preceded it. Later other ice invasions of Illinois occurred, but they covered only the northeastern part of the state. (See state map in Bulletin 123, late Wisconsin glaciation.) These ice sheets did not reach La Salle county, but finely ground rock (rock flour) in immense quantities was carried south by the waters from the melting ice and deposited on the flooded plains, where it was picked

TABLE 1.—SOIL TYPES OF LA SALLE COUNTY

Soil type No.	Name of types	Area in square miles	Area in acres	Percent of total area
	(a) Upland Prairie Soils (page 20)			
926 / 1126	Brown silt loam	922.16	590182.4	79.7143
1126.3	[1]Brown silt loam on till	....	....	......
1120	Black clay loam	6.40	4096.0	.5532
1125	Black silt loam	17.39	11129.6	1.5032
1160	Brown sandy loam	.02	12.8	.0017
	(b) Upland Timber Soils (page 23)			
934 / 1134	Yellow-gray silt loam	94.56	60518.4	8.1741
935 / 1135	Yellow silt loam	41.12	26316.8	3.5545
1199	Rock outcrop	2.40	1536.0	.2074
	(c) Terrace Soils (page 27)			
1526	Brown silt loam	10.26	6566.4	.8869
1526.4	Brown silt loam on gravel[2]	.13	83.2	.0112
1526.5	Brown silt loam on rock	.06	38.4	.0052
1527	Brown silt loam over gravel[2]	5.12	3276.8	.4426
1534.4	Yellow-gray silt loam on gravel	.02	12.8	.0017
1536	Yellow-gray silt loam over gravel	6.68	4275.2	.5774
1560	Brown sandy loam	4.80	3072.0	.4157
1560.4	Brown sandy loam on gravel	.30	192.0	.0259
1560.5	Brown sandy loam on rock	5.73	3667.2	.4953
1564	Yellow-gray sandy loam	.01	6.4	.0008
1581	Dune sand	.04	25.6	.0034
1590	Gravelly loam	.47	300.8	.0406
	(d) Swamp and Bottom-Land Soils (page 31)			
1401	Deep peat	.57	364.8	.0492
1402	Medium peat on clay	.13	83.2	.0112
1426	Deep brown silt loam	11.48	7347.2	.9923
1454	Mixed loam	16.76	10726.4	1.4487
	(e) Residual Soils (page 33)			
060.5	Brown sandy loam on rock	2.38	1523.2	.2057
083	Residual sand	.11	70.4	.0095
	(f) Miscellaneous			
	Shale pits	.54	345.6	.0467
	River	7.19	4601.6	.6216

[1]See map and text for area.

[2]"On" signifies that the gravel or rock is less than 30 inches below the surface; "over," more than 30 inches.


R. I E.
LEE
COUNTY
R. 2 E.
DEKALB R 3 E. COUNTY
LEE COUNTY
T. 36 N.
T. 35 N.
Third Principal Meridian
Mendota
Meriden
Earlville
Triumph
Culton
Troy Grove
Fitchmoor
Four Mile Cr.
Vermillion Cr.
CHICAGO BURLINGTON & QUINCY
CHICAGO & NORTHWESTERN
CHICAGO MILWAUKEE & ST. PAUL
CHICAGO

SOIL SURVEY MAP OF LASALLE COUNTY

UNIVERSITY OF ILLINOIS AGRICULTURAL EXPERIMENT STATION

up by the wind, carried forward, and deposited upon the surface, burying the drift material of the early Wisconsin glaciation to a depth of 2 to 10 feet or more. This wind-blown material, called loess, represents a mixture of all kinds of material over which the glacier passed.

After the loessial material was deposited over the surface of the country, vegetation developed, and organic matter became incorporated with the loess to a greater or less extent, thus gradually changing it into normal soil. Surface washing has made additional modifications.

Table 1 shows the area of each type of soil in the county and its percentage of the total area.

It will be noted that four-fifths of the entire county is covered with the common prairie soil, known as brown silt loam, while the black silt loam and black clay loam (sometimes called "black gumbo"), occupying the flat upland prairie, aggregate only 2 percent.

About 8 percent of the county consists of yellow-gray silt loam, the undulating upland soil once covered with timber. The more rolling yellow silt loam, also timber upland, is nearly half as extensive.

The terrace types cover 3 percent of the area of the county and the bottom lands and rivers also about 3 percent.

The accompanying maps show the location and boundary lines of every type of soil in the county, even down to areas of a few acres; and in Table 2 are reported the amounts of organic carbon (the best measure of the organic matter) and the total amounts of the five important elements of plant food contained in 2 million pounds of the surface soil of each type (the plowed soil of an acre about 6⅔ inches deep). In addition, the table shows the amount of limestone present, if any, or the amount of limestone required to neutralize the acidity existing in the soil.[1]

THE INVOICE AND INCREASE OF FERTILITY IN LA SALLE COUNTY SOILS

SOIL ANALYSIS

In order to avoid confusion in applying in a practical way the technical information contained in this report, the results are given in the most simplified form. The composition reported for a given soil type is, as a rule, the average of many analyses, which, like most things in nature, show more or less variation; but for all practical purposes the average is most trustworthy and sufficient. (See Bulletin 123, which reports the general soil survey of the state, together with many hundred individual analyses of soil samples representing twenty-five of the most important and most extensive soil types in the state.)

[1]The figures given in Table 2 (and in the corresponding tables for subsurface and subsoil) are the averages for all determinations made, with the exception of the acidity or the limestone present in two soil types. As a rule, the brown silt loam is slightly acid in the surface and subsurface, and sometimes the acidity extends to the subsoil, but where samples were taken from the heavier phase of this type (near old draws or perhaps near the shore lines of what may once have been ponds) an abundance of lime carbonate was usually found in the subsoil and, in a few cases, even in the surface and subsurface, as is shown in the tables. The other exception occurred with one sample of subsoil of the yellow-gray silt loam, which showed the presence of limestone, but this stratum, as well as the surface and subsoil, is usually acid, and consequently this exceptional result was not included in the average.

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but, as explained in the Appendix, the rate of liberation is governed by many factors. Also, as there stated, probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that the productive power of normal soil in humid sections depends upon the stock of plant food contained in the soil and upon the rate at which it is liberated.

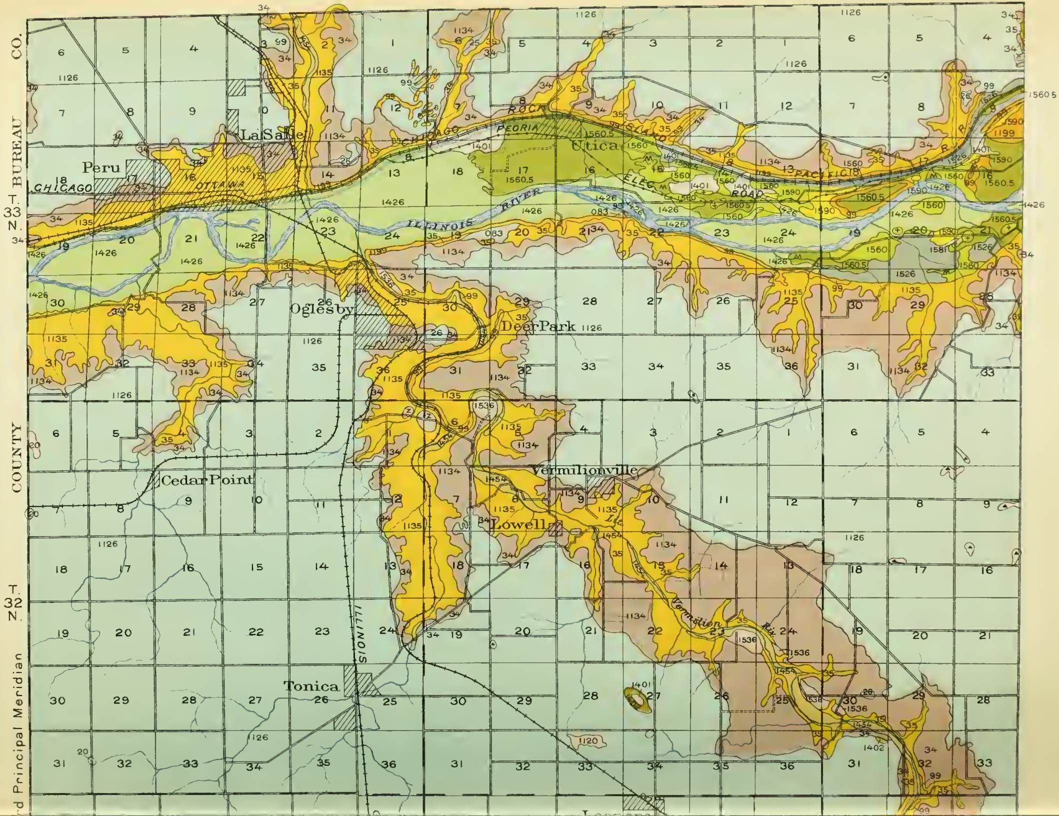
The fact may be repeated, too, that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all plants, only one (hydrogen) from water, while seven are secured from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes) in case the amount liberated from the soil is insufficient. But even the leguminous plants (which include the clovers, peas, beans, alfalfa, and vetches), in common with other agricultural plants, secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron, and sulfur) and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

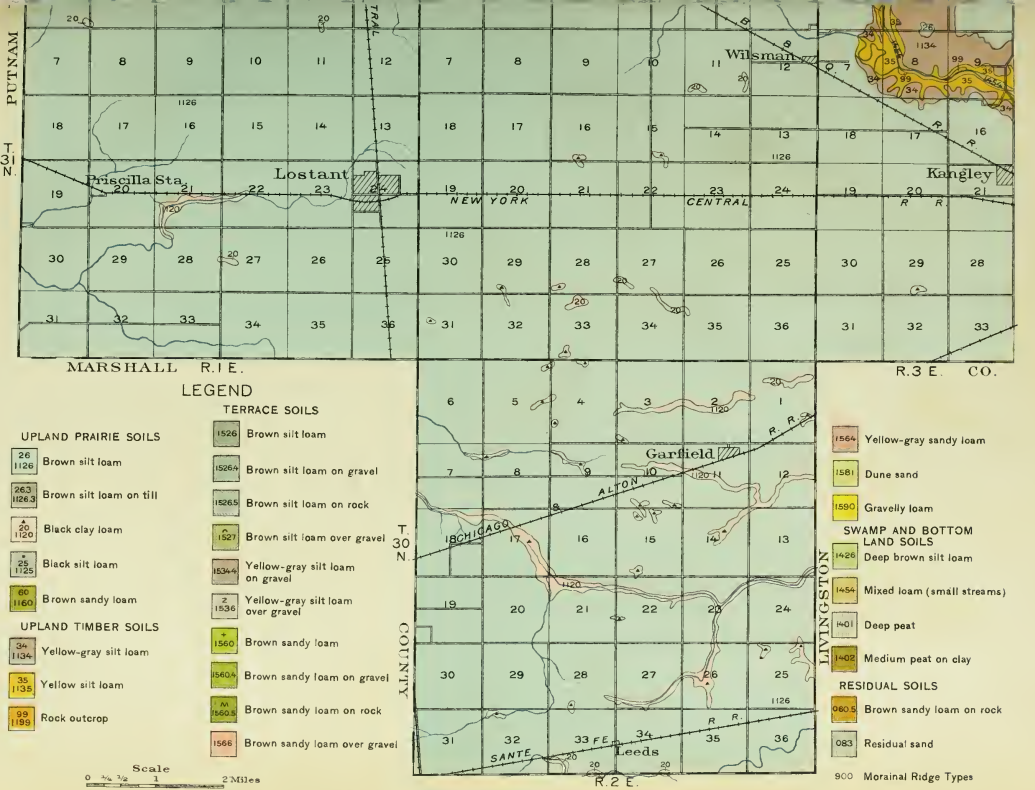
Table A in the Appendix shows the requirements of large crops for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally from natural sources in sufficient abundance, compared with the amounts needed by plants, so that they are never known to limit the yield of common farm crops.)

As stated, the data in Table 2 represent the total amounts of plant-food elements found in 2 million pounds of surface soil,[1] which corresponds to an acre about 6⅔ inches deep. This includes at least as much soil as is ordinarily turned with the plow, and represents that part with which the farm manure, limestone, phosphate, or other fertilizer applied in soil improvement is incorporated. It is the soil stratum that must be depended upon in large part to furnish the necessary plant food for the production of crops, as will be seen from the information given in the Appendix. Even a rich subsoil has little or no value if it lies beneath a worn-out surface, but if the fertility of the surface soil is maintained at a high point, then the strong, vigorous plants will have power to secure more plant food from the subsurface and subsoil than would weak, shallow-rooted plants.

By easy computation it will be found that the most common prairie soil of La Salle county does not contain more than enough total nitrogen in the plowed soil for the production of maximum crops for twelve rotations; while the upland timber soils contain, as an average, less than one-half as much nitrogen as the prairie land.

[1]In all strata the weight of peat is figured at ½ and that of sand at 1¼ the weight of normal soils.


BUREAU CO.
T. 33 N.
COUNTY
T. 32 N.
rd Principal Meridian
Peru
LaSalle
Utica
Oglesby
Deer Park
Cedar Point
Vermilionville
Lowell
Tonica
ILLINOIS RIVER
Vermilion Riv.
CHICAGO ROCK ISLAND R.R.
PACIFIC
CHICAGO OTTAWA
PEORIA
ELEC. ROAD
ILLINOIS



SOIL SURVEY MAP OF LASALLE COUNTY
UNIVERSITY OF ILLINOIS AGRICULTURAL EXPERIMENT STATION

TABLE 2.—FERTILITY IN THE SOILS OF LA SALLE COUNTY, ILLINOIS

Average pounds per acre in 2 million pounds of surface soil (about 0 to 6⅔ inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone requir'd
	Upland Prairie Soils								
1126	Brown silt loam	71390	6102	1384	33474	9567	15158	rarely	often
1126.3	Brown silt loam on till	42200	4360	1180	38520	11200	8420		40
1120	Black clay loam	81460	7020	1780	36440	13480	20300	1960	
1125	Black silt loam.	74660	6850	1970	34980	13380	21270	14850	
1160	Brown sandy loam.	33100	2820	1160	28720	5480	7400		40
	Upland Timber Soils								
1134	Yellow-gray silt loam	32673	2527	1033	38580	7053	8227		87
1135	Yellow silt loam	23967	2093	773	39033	7560	7100		200
	Terrace Soils								
1526	Brown silt loam	65520	5720	1860	56260	16667	12000	2620	
1526.4	Brown silt loam on gravel. ..	42760	3880	1100	33740	7120	8720		40
1526.5	Brown silt loam on rock.......	135800	11460	4900	46380	14680	21880	2780	
1527	Brown silt loam over gravel...	40440	3700	1020	35680	7940	8920		60
1534.4	Yellow-gray silt loam on gravel	29120	2740	980	35560	6280	9020		40
1536	Yellow-gray silt loam over gravel......	29080	2700	980	37900	6500	8380		60
1560	Brown sandy loam.........	29240	2480	1210	19110	3560	5430		80
1560.4	Brown sandy loam on gravel	25700	2260	1360	25980	4760	4740		80
1560.5	Brown sandy loam on rock..	52780	5000	1240	13120	5840	11920	9900	
1564	Yellow-gray sandy loam over gravel..	19120	1560	740	30480	4600	8980	4300	
1581	Dune sand	13500	1300	780	23530	4000	5880		80
1590	Gravelly loam..	64560	5960	1920	25580	11220	17420	11460	
	Swamp and Bottom-Land Soils								
1426	Deep brown silt loam..	52460	4440	2020	37960	30000	62760	209500	
1454	Mixed loam (small streams)	42740	4440	1260	33500	27420	46880	161900	
1401	Deep peat......	177540	16080	1310	8210	8370	129900	285850	
1402	Medium peat on clay.......	212320	19600	970	10730	5140	16270		90
	Residual Soils								
060.5	Brown sandy loam on rock..	26400	2220	880	25880	4480	1800		20
083	Residual sand..	16380	850	700	7900	2530	2650	4530	

With respect to phosphorus, the condition differs only in degree, nine-tenths of the soil area of the county containing no more of that element than would be required for eighteen crop rotations if such crop yields were secured as are suggested in Table A of the Appendix. In the case of the

cereals it will be seen from the same table that about three-fourths of the phosphorus taken from the soil is deposited in the grain, while only one-fourth remains in the straw or stalks.

On the other hand, the potassium is sufficient for 25 centuries if only the grain is sold, or for 400 years even if the total crops should be removed and nothing returned. The corresponding figures are about 2500 and 600 years for magnesium, and about 15,000 and 350 years for calcium.

Thus, when measured by the actual crop requirements for plant food, potassium is no more limited than magnesium and calcium, and, as explained in the Appendix, with these elements we must also consider the heavier loss by leaching.

These general statements relating to the total quantities of plant food in the plowed soil certainly emphasize the fact that the supplies of some of these necessary elements of fertility are extremely limited when measured by the needs of large crop yields for even one or two generations of people.

The variation among the different soil types with respect to their content of important plant-food elements is also very marked. Thus, the prairie soils contain from two to three times as much nitrogen as the timber lands of the same topography; and the richest prairie land contains twice as much phosphorus as the common upland timber soils.

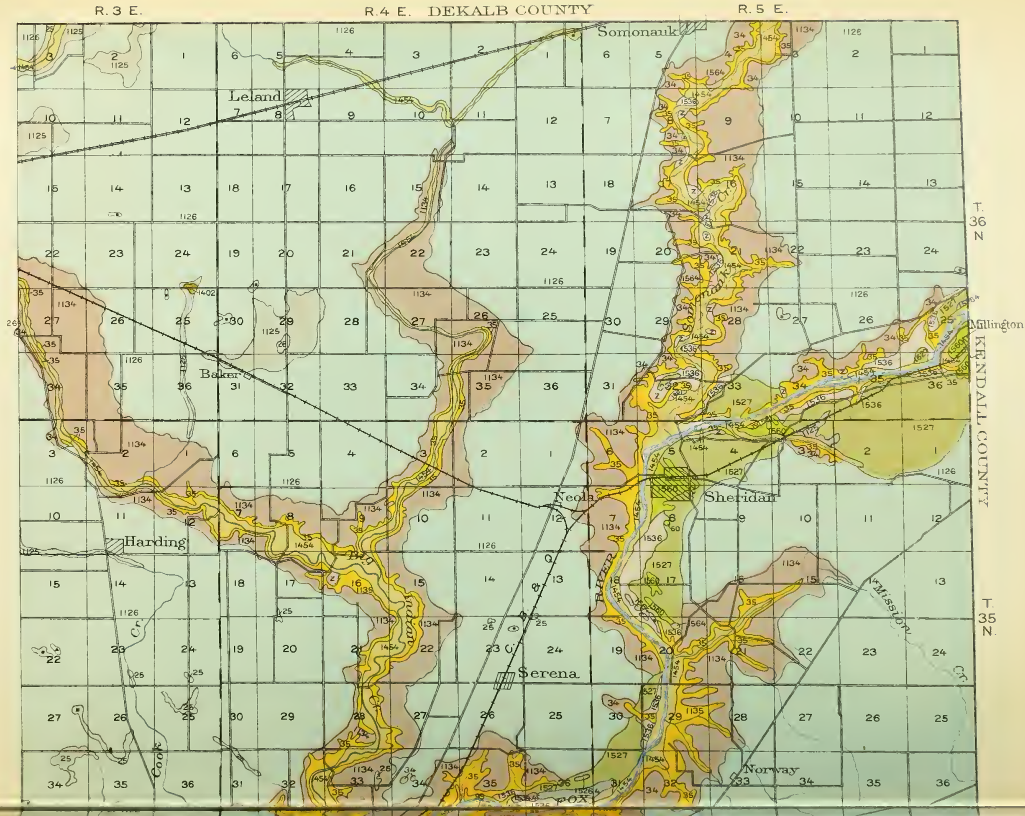
On the other hand, the most significant fact revealed by the investigation of the La Salle county soils is the low phosphorus content of the common brown silt loam prairie, a type of soil which covers more than three-fourths of the entire county. The market value of this land is about $200 an acre, and yet an application of forty dollars' worth of fine-ground raw rock phosphate would double the phosphorus content of the plowed soil, and, if properly made, would in the near future double the yield of clover on the normal and lighter phases. If the clover was then returned to the soil, either directly or in farm manure, the combined effect of phosphorus and increased nitrogenous organic matter, with a good rotation of crops, would in time double the yield of corn on most farms.

With 6,000 pounds of nitrogen in the soil and an inexhaustible supply in the air, with 34,000 pounds of potassium in the same soil and with practically no acidity, the economic loss in farming such land with only 1300 pounds of total phosphorus in the plowed soil can be appreciated only by the man who fully realizes that the crop yields could ultimately be doubled by adding phosphorus,—without change of seed or season and with very little more work than is now devoted to the fields.

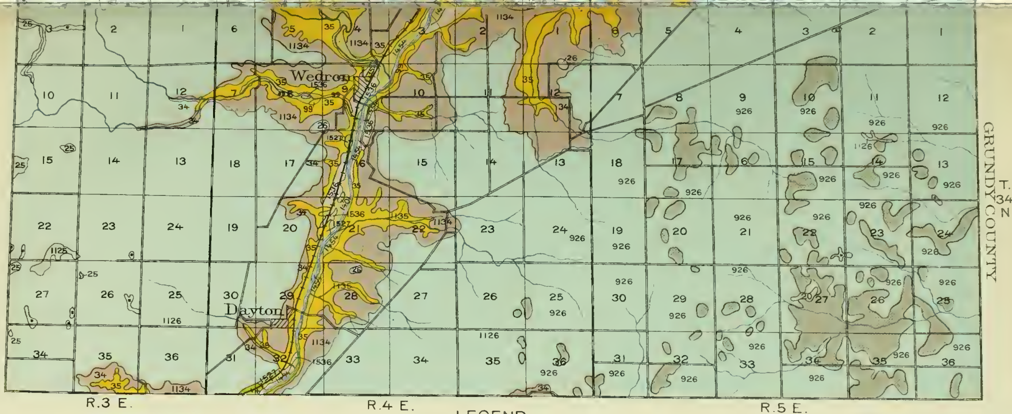
Fortunately, some definite field experiments have already been conducted on this most extensive type of soil, not in La Salle county, but on similar soil in several other counties, as at Urbana in Champaign county, at Sibley in Ford county, and at Bloomington in McLean county.

RESULTS OF FIELD EXPERIMENTS AT URBANA

A three-year rotation of corn, oats, and clover was begun on the North Farm at the University of Illinois in 1902, on three fields of typical brown silt loam prairie land which, after twenty years or more of pasturing, had grown corn in 1895, 1896, and 1897 (when careful records were kept of the yields produced) and had then been cropped with clover and grass on one field, oats on another, and oats, cowpeas, and corn on the third field, until 1901.



R. 3 E.
R. 4 E.
DEKALB COUNTY
R. 5 E.
Somonauk
Leland
Baker
Harding
Neola
Sheridan
Serena
Norway
Millington
KENDALL COUNTY
T. 36 N
T. 35 N.
FOX
RIVER
Somonauk Cr.
Big Indian Cr.
Mission Cr.
Cook Cr.



LEGEND

UPLAND PRAIRIE SOILS

- 26 / 1126 Brown silt loam
- 263 / 11263 Brown silt loam on till
- 20 / 1120 Black clay loam
- 25 / 1125 Black silt loam
- 60 / 1160 Brown sandy loam

UPLAND TIMBER SOILS

- 34 / 1134 Yellow-gray silt loam
- 35 / 1135 Yellow silt loam
- 99 / 1199 Rock outcrop

TERRACE SOILS

- 1526 Brown silt loam
- 1526.4 Brown silt loam on gravel
- 1526.5 Brown silt loam on rock
- 1527 Brown silt loam over gravel
- 1534.4 Yellow-gray silt loam on gravel
- 1536 Yellow-gray silt loam over gravel
- 1560 Brown sandy loam
- 1560.4 Brown sandy loam on gravel
- 1560.5 Brown sandy loam on rock
- 1566 Brown sandy loam over gravel
- 1564 Yellow-gray sandy loam
- 1581 Dune sand
- 1590 Gravelly loam

SWAMP AND BOTTOM LAND SOILS

- 1426 Deep brown silt loam
- 1454 Mixed loam (small streams)
- 1401 Deep peat
- 1402 Medium peat on clay

RESIDUAL SOILS

- 060.5 Brown sandy loam on rock
- 083 Residual sand

900 Morainal Ridge Types

Scale
0 1/4 1/2 1 2 Miles

SOIL SURVEY MAP OF LASALLE COUNTY
UNIVERSITY OF ILLINOIS AGRICULTURAL EXPERIMENT STATION

A.Hoen & Co.Baltimore

As an average of the first three years (1902-1904) phosphorus increased the crop yields per acre by .68 ton of clover, 8.8 bushels of corn, and 1.9 bushels of oats.

During the second three years (1905-1907) it produced average increases of .79 ton of clover, 13.2 bushels of corn, and 11.9 bushels of oats.

During the third course of the rotation (1908-1910) it produced average increases of 1.05 tons of clover, 18.7 bushels of corn, and 8.4 bushels of oats.

For convenient reference the results are summarized in Table 3 (page 10).

Wheat is grown on the University South Farm in a rotation experiment started more recently. As an average of the four years 1908 to 1911, raw

PLATE 1. WHEAT IN 1911 ON URBANA FIELD
COVER CROPS AND CROP RESIDUES PLOWED UNDER
AVERAGE YIELD, 35.2 BUSHELS PER ACRE

TABLE 3.—EFFECT OF PHOSPHORUS ON BROWN SILT LOAM AT URBANA
(Average increase per acre)

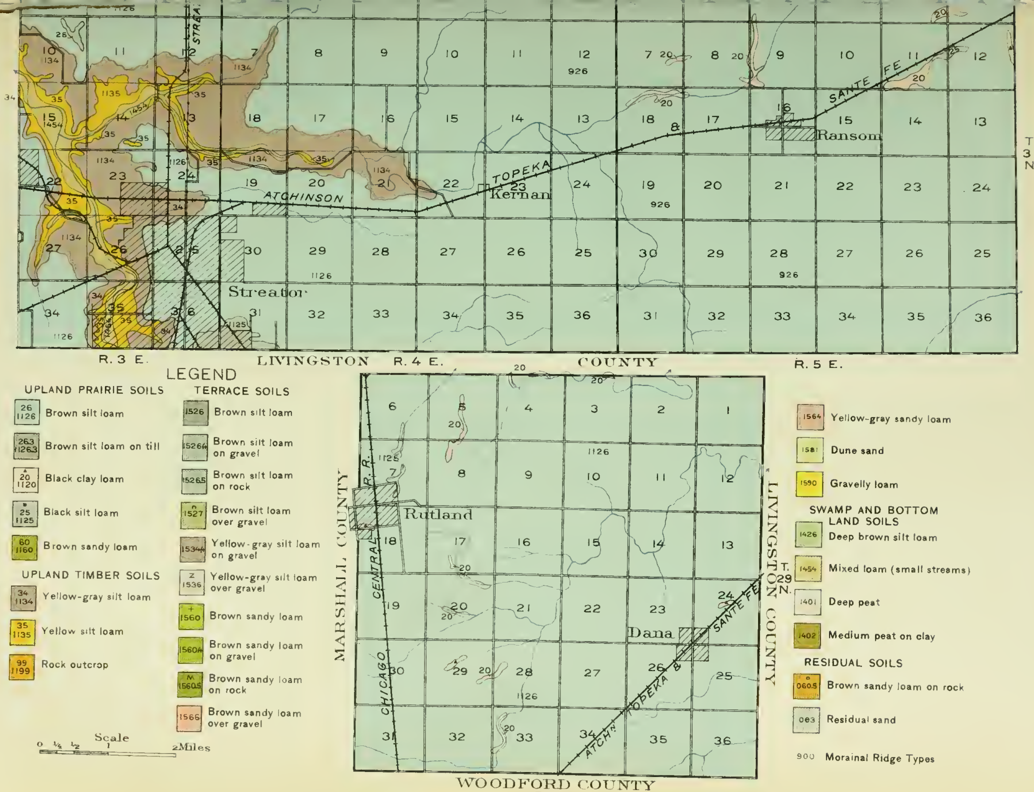
Rotation	Years	Corn, bu.	Oats, bu.	Clover, tons	Value of increase	Cost of treatment[1]
First..........	1902,-3,-4	8.8	1.9	.68	$ 7.73	$7.50
Second	1905,-6,-7	13.2	11.9	.79	12.93	7.50
Third.........	1908,-9,-10	18.7	8.4	1.05	15.37	7.17

[1]Prices used are 35 cents a bushel for corn, 30 cents for oats, $6 a ton for clover hay, 10 and 3 cents a pound, respectively, for phosphorus in bone meal and in rock phosphate.

rock phosphate (with no previous application of bone meal) increased the yield of wheat by 10.3 bushels per acre. Here too, as an average of the four years, the phosphorus applied paid back about twice its cost.

PLATE 2. WHEAT IN 1911 ON URBANA FIELD
COVER CROPS AND CROP RESIDUES PLOWED UNDER
FINE-GROUND ROCK PHOSPHATE APPLIED
AVERAGE YIELD, 50.1 BUSHELS PER ACRE

Marseilles
Seneca
OTTAWA
Grand Ridge
GRUNDY COUNTY
T. 33 N.
T. 32 N.
CHICAGO ROCK ISLAND & PACIFIC R.R.
CHICAGO OTTAWA & PEORIA
MICHIGAN
ELECTRIC
OTTAWA
Walbridge Cr.
Kickapoo Cr.
SHALE PIT



SOIL SURVEY MAP OF LASALLE COUNTY

UNIVERSITY OF ILLINOIS AGRICULTURAL EXPERIMENT STATION

Wheat has also been grown on the North Farm during the last two years, and the average increase produced by phosphorus (part in bone meal and part in raw phosphate) has been 11 bushels per acre.

In the grain system of farming, the yield of wheat in 1911 was 35.2 bushels per acre where cover crops and crop residues are plowed under without the use of phosphorus; but where rock phosphate is used the average yield was 50.1 bushels. (See Plates 1 and 2.)

In the live-stock system, the yield of wheat in 1911 was 34.2 bushels where manure and cover crops are used without phosphate, and 51.8 bushels, as an average, where rock phosphate is used in addition. (See Plates 3 and 4.)

These results emphasize the cumulative effect of permanent systems of soil improvement.

Plate 3. Wheat in 1911 on Urbana Field
Cover Crops and Farm Manure Plowed Under
Average Yield, 34.2 Bushels Per Acre

RESULTS OF EXPERIMENTS ON SIBLEY FIELD

Table 4 gives the results obtained during the past eleven years from the Sibley soil experiment field located in Ford county on typical brown silt loam prairie of the Illinois corn belt.

Previous to 1902 this land had been cropped with corn and oats for many years under a system of tenant farming, and the soil had become somewhat deficient in active organic matter. While phosphorus was the limiting element of plant food, the supply of nitrogen becoming available annually was but little in excess of the phosphorus, as is well shown by the corn yields for 1903, when phosphorus produced an increase of 8 bushels, nitrogen without phosphorus produced no increase, but nitrogen and phosphorus together increased the yield by 15 bushels.

After six years of additional cropping, however, nitrogen appears to have become the most limiting element, the increase in the corn in 1907 having

PLATE 4. WHEAT IN 1911 ON URBANA FIELD
COVER CROPS AND FARM MANURE PLOWED UNDER
FINE-GROUND ROCK PHOSPHATE APPLIED
AVERAGE YIELD, 51.8 BUSHELS PER ACRE

TABLE 4.—CROP YIELDS IN SOIL EXPERIMENTS, SIBLEY FIELD

Brown silt loam prairie; early Wisconsin glaciation		Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912
Plot	Soil treatment applied	Bushels per acre										
101	None	57.3	50.4	74.4	29.5	36.7	33.9	25.9	25.3	26.6	20.7	84.4
102	Lime	60.0	54.0	74.7	31.7	39.2	38.9	24.7	28.8	34.0	22.2	85.6
103	Lime, nitrogen	60.0	54.3	77.5	32.8	41.7	48.1	36.3	19.0	29.0	22.4	25.3
104	Lime, phosphorus	61.3	62.3	92.5	36.3	44.8	43.5	25.6	32.2	52.0	31.6	92.3
105	Lime, potassium	56.0	49.9	74.4	30.2	37.5	34.9	22.2	23.2	34.2	21.6	83.1
106	Lime, nitrogen, phosphorus	57.3	69.1	88.4	45.2	68.5	72.3	45.6	33.3	55.6	35.3	42.2
107	Lime, nitrogen, potassium	53.3	51.4	75.9	37.7	39.7	51.1	42.2	25.8	46.2	20.1	55.6
108	Lime, phosphorus, potassium	58.7	60.9	80.0	39.8	41.5	39.8	27.2	28.5	43.0	31.8	79.7
109	Lime, nitrogen, phos., potas.	58.7	65.9	82.5	48.0	69.5	80.1	52.8	35.0	58.0	35.7	57.2
110	Nitro., phos., potassium	60.0	60.1	85.0	48.5	63.3	72.3	44.1	30.8	64.4	31.5	54.1

Average Increase: Bushels per Acre

	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912
For nitrogen	−1.7	3.4	.7	6.4	14.1	23.6	19.3	.1	6.4	1.6	-40.1
For phosphorus	1.7	12.1	10.7	9.2	16.5	15.7	6.4	8.1	16.3	12.0	5.4
For potassium	−3.0	−2.9	−5.1	2.4	−1.5	1.0	3.0	− .2	2.7	− .6	7.5
For nitro., phos., over phos.	−4.0	6.8	−4.1	8.9	23.7	28.8	20.0	1.1	3.6	3.7	−50.1
For phos., nitro. over nitro	−2.7	14.8	10.9	12.4	26.8	24.2	9.3	14.3	26.6	12.9	16.9
For potas., nitro., phos. over nitro., phos.	1.4	−3.2	−5.9	2.8	1.0	7.8	7.2	1.7	2.4	.4	15.0

Value of Crops per Acre in Eleven Years

Plot	Soil treatment applied	Total value of eleven crops	Value of increase
101	None	$ 172.73	
102	Lime	184.75	$ 12.02
103	Lime, nitrogen	167.42	— 5.31
104	Lime, phosphorus	214.50	41.77
105	Lime, potassium	173.22	.49
106	Lime, nitrogen, phosphorus	233.15	60.42
107	Lime, nitrogen, potassium	188.19	15.46
108	Lime, phosphorus, potassium	200.37	27.64
109	Lime, nitrogen, phosphorus, potassium	244.62	71.89
110	Nitrogen, phosphorus, potassium	233.54	60.81

Average Value of Increase per Acre in Eleven Years		Cost of increase
For nitrogen	$ 15.14	$ 165.00
For phosphorus	44.76	27.50
For potassium	1.65	27.50
For nitrogen and phosphorus over phosphorus	18.65	165.00
For phosphorus and nitrogen over nitrogen	65.73	27.50
For potassium, nitrogen, and phosphorus over nitrogen and phosphorus	11.47	27.50

been 9 bushels from nitrogen and only 5 bushels from phosphorus, while both together produced an increase of 33 bushels. By comparing the corn yields for the four years 1902, 1903, 1906, and 1907, it will be seen that the untreated land has apparently grown less productive, whereas on land receiving both phosphorus and nitrogen the yield has appreciably increased, so that in 1907, when the untreated rotated land produced only 34 bushels of corn per acre, a yield of 72 bushels (more than twice as much) was produced where lime, nitrogen, and phosphorus had been applied, altho the two plots produced exactly the same yield (57.3 bushels) in 1902.

Even in the unfavorable season of 1910, the yield of the highest-producing plot exceeded that of 1902, while the untreated land produced less than half as much as was produced in 1902. The prolonged drouth of 1911 resulted in almost a failure of the corn crop, but nevertheless the effect of soil treatment is seen. Phosphorus appears to have been the first limiting element again in 1909, 1910, and 1911; while the lodging of oats, especially on the nitrogen plots, in the exceptionally favorable season of 1912, produced very irregular results.

In the lower part of Table 4 are shown the total values per acre of the eleven crops from each of the ten different plots, the amounts varying from $167.42 to $244.62; also the value of the increase produced in crop yields above the value of the yields from the untreated land, corn being valued at 35 cents a bushel, oats at 30 cents, and wheat at 70 cents. Phosphorus without nitrogen produced $29.75 in addition to the increase by lime; but, with nitrogen, it produced $65.73 above the crop values where only lime and nitrogen were used. The results show that in 25 cases out of 44 the addition of potassium decreased the crop yields. Even under the most favorable conditions, and with no effort to liberate potassium from the soil by adding organic matter, potassium paid back less than half its cost.

By comparing Plots 101 and 102, and also 109 and 110, it will be seen that the average increase produced by lime was $11.55, or more than $1 an acre a year. Altho this increase may have been above normal on these plots because of the "condition" of the soil at the beginning, it suggests that the time is here when limestone must be applied to some of these brown silt loam soils. While nitrogen produced an appreciable increase, especially when phosphorus was provided, the only conclusion to be drawn, if we are to utilize this fact to advantage, is that the nitrogen must be secured from the air.

RESULTS OF EXPERIMENTS ON BLOOMINGTON FIELD

Space is taken to insert Table 5, giving all of the results thus far obtained from the Bloomington soil experiment field, which is also located on the brown silt loam prairie soil of the Illinois corn belt.

The general results of the eleven years' work on the Bloomington field tell much the same story as those from the Sibley field. The rotations differed by the use of clover and by discontinuing the use of commercial nitrogen on the Bloomington field after 1905, in consequence of which phosphorus without commercial nitrogen (Plot 104) produced an even larger increase ($89.92) than was produced by phosphorus over nitrogen ($65.73) on the Sibley field (see Plots 103 and 106).

It should be stated that a draw runs near Plot 110 on the Bloomington field, that the crops on that plot are sometimes damaged by overflow or imperfect drainage, and that Plot 101 occupies the lowest ground on the oppo-

site side of the field. In part because of these irregularities and in part because only one small application has been made, no conclusions can be drawn in regard to lime. Otherwise all results reported in Table 5 are considered reliable. They not only furnish much information in themselves but also instructive comparisons with the Sibley field.

Wherever nitrogen was provided, either by direct application or by the use of legume crops, the addition of the element phosphorus produced very marked increases, the average value for the two fields being $7.07 an acre a year. This is $4.57 above its cost in 200 pounds of steamed bone meal, the form in which it was applied to the Sibley and Bloomington fields. On the other hand, the use of phosphorus without nitrogen will not maintain the fertility of the soil (see Plots 104 and 106, Sibley field). As the only practical and profitable method of supplying the nitrogen, a liberal use of clover or other legumes is suggested, the legume to be plowed under either directly or as manure, preferably in connection with the phosphorus applied, especially if raw rock phosphate is used.

From the soil of the best treated plots, 160 pounds per acre of phosphorus, as an average, were removed in the eleven crops. This is equal to more than 13 percent of the total phosphorus contained in the surface soil of an acre of the untreated land. In other words, if such crops could be grown for eighty years, they would require as much phosphorus as the total supply in the ordinary plowed soil. The results plainly show, however, that without the addition of phosphorus such crops cannot be grown year after year. Where no phosphorus was applied, the crops removed only 107 pounds of phosphorus in the eleven years, which is equivalent to only 9 percent of the total amount (1,200 pounds) in the surface soil at the beginning (1902). The total phosphorus applied from 1902 to 1912, as an average of all plots where it was used, amounted to 275 pounds per acre and cost $27.50. This paid back $84.91, or 300 percent on the investment; whereas potassium, used in the same number of tests and at the same cost, paid back only $1.59 per acre in the eleven years, or less than 6 percent of its cost. Are not these results to be expected from the composition of the soil and the requirements of crops? (See Table 2, page 7, and also Table A in the Appendix.)

Nitrogen was applied to this field in commercial form only, from 1902 to 1905; but clover was grown in 1906 and 1910, and a catch crop of cowpeas after the clover in 1906. The cowpeas were plowed under on all plots, and the 1910 clover (except the seed) was plowed under on five plots (103, 106, 107, 109, and 110). Straw and corn stalks have also been returned to these plots in recent years. The effect of returning these residues to the soil is already appreciable (an average increase of 4.4 bushels of wheat in 1910 and 7.9 bushels of corn in 1911) and probably will be more marked on subsequent crops. Indeed, the large crops of corn, oats, and wheat grown on Plots 104 and 108 during the eleven years drew their nitrogen very largely from the natural supply in the organic matter of the soil.

The clover roots and stubble contain no more nitrogen than the clover crop takes from the soil, but they decay rapidly in contact with the soil and probably hasten the decomposition of the soil humus and the consequent liberation of the soil nitrogen. But of course there is a limit to the reserve stock of humus and nitrogen remaining in the soil, and the future years will undoubtedly witness a gradually increasing difference between Plots 104 and 106 and between Plots 108 and 109, in the yields of grain crops.

TABLE 5.—CROP YIELDS IN SOIL EXPERIMENTS, BLOOMINGTON FIELD

Brown silt loam prairie; early Wisconsin glaciation		Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Corn 1908	Oats 1909	Clover[2] 1910	Wheat 1911	Corn 1912
Plot	Soil treatment applied	Bushels or tons per acre										
101	None	30.8	63.9	54.8	30 8	.39	60.9	40.3	46.4	1.56	22.5	55.2
102	Lime	37.0	60.3	60.8	28.8	.58	63.1	35.3	53.6	1.09	22.6	47.9
103	Lime, crop res.[1]	35.1	59.5	69.8	30.5	.46	64.3	36.9	49.4	(.83)	25.6	62.5
104	Lime, phosphorus	41.7	73.0	72.7	39.2	1.65	82.1	47.5	63.8	4.21	57.6	74.5
105	Lime, potassium	37.7	56.4	62.5	33.2	.51	64.1	36.2	45.3	1.26	21.7	57.8
106	Lime, residues,[1] phosphorus	43 9	77.6	85.3	50.9	[3]	78.9	45.8	72.5	(1.67)	60.2	86.1
107	Lime, residues,[2] potassium	40.4	58.9	66.4	29.5	.81	64.3	31.0	51.1	(.33)	27.3	58.9
108	Lime, phosphorus, potassium	50.1	74.8	70 3	37.8	2.36	81.4	57.2	59.5	3.27	54.0	79.2
109	Lime, res.,[1] phos., potassium	52.7	80.9	90.5	51.9	[3]	88.4	58.1	64.2	(.42)	60.4	83.4
110	Res , phosphorus, potassium	52.3	73.1	71.4	51.1	[3]	78.0	51.4	55.3	(.60)	61.0	78.3

Average Increase: Bushels or Tons per Acre

	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Corn 1908	Oats 1909	Clover 1910	Wheat 1911	Corn 1912
For residues	1.4	3.1	11.4	5.9	−.96	1.3	−1.1	3.7	−1.64	4.4	7.9
For phosphorus	9.5	17.8	14.8	14.4	.41	18.8	18.0	15.1	1.51	33.9	24.0
For potassium	5.8	.2	.3	.7	.25	2.4	4.2	−4.8	−.63	−.6	2.1
For res., phos. over phos.	2.2	4.6	12.6	11.7	−.65	−3.2	−1.7	8.7	−2.25	2.6	11.6
For phos., res. over res.	8.8	18.1	15.5	20.4	−1.46	14.6	8.9	23.1	.84	34.6	23.6
For potas., res., phos. over res., phos.	8.8	3.3	5.2	1.0	.00	9.5	12.3	−8.3	−1.25	.2	−2.7

Value of Crops per Acre in Eleven Years

Plot	Soil treatment applied	Total value of eleven crops	Value of increase
101	None	$167.22	
102	Lime	165.52	−$1.70
103	Lime, residues	173.17	5.95
104	Lime, phosphorus	255.44	88.22
105	Lime, potassium	169.66	2.44
106	Lime, residues, phosphorus	251.43	84.21
107	Lime, residues, potassium	170.57	3.35
108	Lime, phosphorus, potassium	256 92	89.70
109	Lime, residues, phosphorus, potassium	254.76	87.54
110	Residues, phosphorus, potassium	236.66	69.44

Average Value of Increase per Acre in Eleven Years		Cost of increase
For residues	$ .60	?
For phosphorus	84.91	$27.50
For potassium	1.59	27.50
For residues and phosphorus over phosphorus	−4 01	?
For phosphorus and residues over residues	78.26	27.50
For potassium, residues, and phosphorus over residues and phosphorus	3.33	27.50

[1]Commercial nitrogen was used 1902–1905.
[2]The figures in parentheses mean bushels of seed; the others, tons of hay.
[3]Clover smothered by previous wheat crop.

In Plate 5 are shown graphically the relative values of the eleven crops for the eight comparable plots, Nos. 102 to 109. The cost of the phosphorus is indicated by that part of the diagram above the short crossbars. It should be kept in mind that no value is assigned to clover plowed under except as it reappears in the increase of subsequent crops. Plots 106 and 109 are heavily handicapped because of the clover failure on those plots in 1906 and the poor yield of clover seed in 1910, whereas Plots 104 and 108 produced a fair crop in 1906 and a very large crop in 1910. As an average, Plots 106 and 109 are only $3.09 behind Plots 104 and 108 in the value of the eleven crops harvested, and this would have been covered by about ½ bushel more clover seed in 1906 or 1910, or it may be covered by 10 bushels more corn in 1913. The values from Plots 103 and 107 average $4.28 more than the values from Plots 102 and 105. (See also last page of cover.)

THE SUBSURFACE AND SUBSOIL

In Tables 6 and 7 are recorded the amounts of plant food in the subsurface and the subsoil, but it should be remembered that these supplies are of little value unless the top soil is kept rich. Probably the most important information contained in Tables 6 and 7 is that the most common upland timber soil is usually more strongly acid in the subsurface and subsoil than in the surface, thus emphasizing the importance of having plenty of lime-

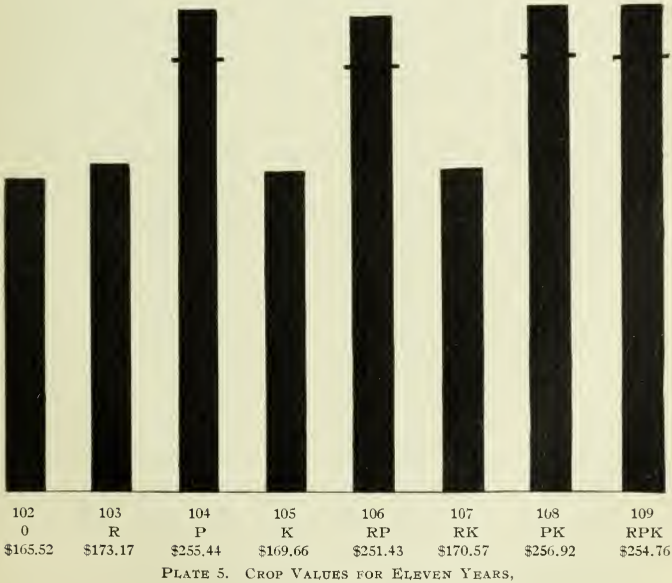


PLATE 5. CROP VALUES FOR ELEVEN YEARS, BLOOMINGTON EXPERIMENT FIELD

stone in the surface soil to neutralize the acid moisture which rises from the lower strata by capillary action during periods of partial drouth, which are critical periods in the life of such plants as clover. While the common brown silt loam prairie soil is usually slightly acid, the upland soils that are

TABLE 6.—FERTILITY IN THE SOILS OF LA SALLE COUNTY, ILLINOIS
Average pounds per acre in 4 million pounds of subsurface (about $6\frac{2}{3}$ to 20 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone requir'd
	Upland Prairie Soils								
1126	Brown silt loam	69139	6163	2184	69646	22877	22973	rarely	often
1126.3	Brown silt loam on till	38520	4160	1480	88560	33520	14040		80
1120	Black clay loam	82360	7560	2840	72320	26160	37960	2040	
1125	Black silt loam	52720	5280	2920	74040	27360	36260	16620	
1160	Brown sandy loam	34360	3080	1720	60440	16000	16000		1480
	Upland Timber Soils								
1134	Yellow-gray silt loam	23947	2280	1907	81853	20840	15187		1427
1135	Yellow silt loam	17947	2280	1387	90000	27813	10580		8000
	Terrace Soils								
1526	Brown silt loam	76907	7507	3067	119680	44133	30573	55987	
1526.4	Brown silt loam on gravel	56200	5240	1960	67480	21960	18120		120
1526.5	Brown silt loam on rock	198920	16480	10560	94920	30360	49800	15160	
1527	Brown silt loam over gravel	45760	4600	1760	71080	19200	12920		120
1534.4	Yellow-gray silt loam on gravel	19720	2480	2000	70840	20160	17120		80
1536	Yellow-gray silt loam over gravel	15880	2120	1840	79640	20280	16160		440
1560	Brown sandy loam	31680	2900	2040	38380	6860	9740		80
1560.4	Brown sandy loam on gravel	28400	2760	2440	56240	11880	9480		80
1560.5	Brown sandy loam on rock	67720	5880	2480	25160	9920	15440	3920	
1564	Yellow-gray sandy loam over gravel	12440	1600	1680	64480	12760	13280		80
1581	Dune sand	12750	1200	1350	44200	8400	10800		150
1590	Gravelly loam	103760	10000	3680	51800	41280	80360	153720	
	Swamp and Bottom-Land Soils								
1426	Deep brown silt loam	98560	9160	4120	83480	63400	128560	428120	
1454	Mixed loam (small streams)	36560	4560	2040	56520	81600	127880	542960	
1401	Deep peat	546860	46740	2360	14640	15680	157680	265880	
1402	Medium peat on clay	195720	19140	1620	28640	12780	26400	2580	
	Residual Soils								
060.5	Brown sandy loam on rock	13440	1480	1600	57800	11320	1720		1040
083	Residual sand	12000	1200	1250	10450	3600	1800		500

or were timbered are already distinctly in need of limestone, as a rule; and, as already explained, they are even more deficient in phosphorus and nitrogen than the common prairie soil.

TABLE 7.—FERTILITY IN THE SOILS OF LA SALLE COUNTY, ILLINOIS

Average pounds per acre in 6 million pounds of subsoil (about 20 to 40 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Lime stone requir'd
	Upland Prairie Soils								
1126	Brown silt loam	21886	2683	3048	109387	57857	61769	often	rarely
1126.3	Brown silt loam on till.	21300	3660	2400	178200	205620	250320	1167840	
1120	Black clay loam	45240	4500	3360	109320	40320	43200	2580	
1125	Black silt loam.	14610	2370	3840	112020	66090	87480	205830	
1160	Brown sandy loam.........	21120	2700	2520	100380	38220	32820		240
	Upland Timber Soils								
1134	Yellow-gray silt loam.. ...	23500	2460	3280	133040	68360	76760		3510
1135	Yellow silt loam	22840	3100	2540	170560	101860	62240	371520	
	Terrace Soils								
1526	Brown silt loam	50340	5840	3440	178820	90440	92420	347900	
1526.4	Brown silt loam on gravel.....	49560	5100	3360	93300	48060	31440		300
1527	Brown silt loam over gravel...	30540	3420	2940	107700	34920	21720		600
1534.4	Yellow-gray silt loam on gravel								
1536	Yellow-gray silt loam over gravel ...	19260	3180	3600	117360	38520	28020		1440
1560	Brown sandy loam.........	19350	1470	1830	59640	10830	12420		90
1564	Yellow-gray sandy loam over gravel...	11760	1620	2760	83460	22320	17940		420
1581	Dune sand.....	19130	1800	2030	66300	12600	16200		230
	Swamp and Bottom-Land Soils								
1426	Deep brown silt loam..	136200	13740	5820	125340	126000	205140	728040	
1454	Mixed loam (small streams)	20880	2100	2160	68400	137220	261360	1045980	
1401	Deep peat	820290	70110	3540	21960	23520	236520	398820	
1402	Medium peat on clay	49500	4140	3660	102660	135240	395280	1124100	
	Residual Soils								
083	Residual sand..	18000	1800	1880	15680	5400	2700		750

INDIVIDUAL SOIL TYPES

(a) UPLAND PRAIRIE

Brown Silt Loam (1126; *also* 926 *on Moraines*)

This type occupies 922.16 square miles, or 590,182 acres, and constitutes 79.7 percent of the entire area of the county. In topography it varies from flat to rolling, the average being what would be called gently rolling with irregular undulations due to the action of the glacier in thus depositing material. In many places the surface is not sufficiently rolling for good drainage, and it has been necessary to use tile drainage to a large extent.

The soil to a depth of 3 to 5 feet is formed from wind-blown loessial material similar in origin to the deep loess deposits found near the great stream valleys, but finer in physical composition. This type, altho typically a prairie soil, may include in its area a small amount of land that has been forested in comparatively recent time.

The surface soil, 0 to 6⅔ inches, is a brown silt loam, varying on the one hand to black as it grades into black clay loam (1120) or black silt loam (1125), and on the other, to grayish brown or yellowish brown as it grades into the timber types. It contains a sufficient amount of the coarser constituents (coarse silt and sand) to make it work easily and yet enough of fine silt and clay to give it stability. The organic-matter content varies from 4.2 to 8.7 percent, with an average of 5.9 percent; in other words, from 42 to 87 tons per acre, with an average of 59 tons. It is less in the more rolling areas, while in the low and poorly drained parts it is greater, the larger moisture content having permitted a ranker growth of grasses and roots with more favorable conditions for their preservation.

The subsurface stratum varies in thickness from 9 to 16 inches and in color from a dark brown to a yellowish brown silt loam. Both color and depth vary with the topography, being lighter and shallower on the more rolling areas and the areas where this type grades into the timber types.

The beginning of the subsoil is indicated by a change in color and texture. It is a yellow clayey silt or silty clay, somewhat plastic when wet. Where the drainage has been good, it is of a bright or a pale yellow color, but where poorly drained, it approaches an olive.

A phase of this type has been recognized in this county where, by the removal of part of the fine loessial material, the glacial drift or till is found less than 30 inches from the surface. In some places this may give a somewhat inferior soil owing to the compact and less pervious character of the subsoil. But this does not occur very often; most of the till in this type is pervious, and some of it in Townships 33 and 34, Range 5 East, is quite gravelly. Limited areas of sandy and gravelly loam, too small to be shown on the map, are quite common in the morainal regions.

In the management of this type, one very important thing, aside from proper fertilization, tillage, and drainage, is to keep it in good physical condition, or good tilth. It is a common practice in the corn belt to pasture the corn stalks during the winter and, too often, rather late in the spring after the ground has thawed out. This tramping puts the soil in bad condition for working. It becomes partially puddled and will be cloddy as a result. If tramped too late in the spring, the natural agencies of freezing and thawing and wetting and drying, with the aid of ordinary tillage, fail to pro-

duce good tilth before the crop is planted. Whether the crop is corn or oats, it necessarily suffers, and if the season is dry, much damage may result. If the field is put in corn, a poor stand is likely to follow and if put in oats, a compact soil is formed which is unfavorable for their growth. Sometimes farmers work their soil when too wet. This also produces a partial puddling which is unfavorable to physical, chemical, and biological processes. The bad effect will be greater if cropping has reduced the amount of organic matter below the amount that is necessary to maintain good tilth.

Every practicable means should be used to maintain the supply of organic matter. Clover should be grown every three or four years and the bulk of the crop turned under either directly or as manure. All straw should be returned to the land and plowed under if not used for bedding or feed. One of the chief sources of loss of organic matter in the corn belt is the practice of burning the corn stalks. Could the farmers be made to realize how great a loss this entails, they would certainly discontinue the practice. Probably no form of organic matter acts more beneficially in producing good tilth than corn stalks, and to burn them is a very serious waste.

The stalks should be cut up with a disk or stalk cutter and turned under. It is true that they decay rather slowly, but it is also true that their durability in the soil after partial decomposition is exactly what is needed in the maintenance of an adequate supply of humus. A ton of dry corn stalks incorporated with the soil will ultimately furnish as much humus as four tons of average farm manure, but, when burned, both the humus-making material and the nitrogen are forever destroyed and lost.

The normal and the lighter phases of brown silt loam already require liberal additions of nitrogenous organic matter and phosphorus for the increase and maintenance of their crop-producing power. As a rule, limestone can also be added with profit, and the importance of using limestone becomes greater year after year. The heavier phase of this soil type, usually found in narrow areas along old sloughs or draws, is still rich in humus and nitrogen, moderately rich in phosphorus, and well supplied with lime carbonate. Often the soil type in these narrow strips is black silt loam (1125), but it is in too small areas to map separately from the brown silt loam. It should be kept in mind that phosphorus is a constituent of humus and is usually associated with limestone; and phosphorus is not likely to be greatly needed where the soil is still rich in humus and shows the presence of limestone by foaming when moistened with strong hydrochloric acid. (See Circular 150 for detailed directions for testing the soil for limestone or acidity.)

Black Clay Loam (1120)

This type comprises 6.4 square miles, or 4,096 acres, and constitutes about ½ percent of the total area of the county. It occupies the lower and flatter areas where the accumulation of organic matter and finer soil constituents has been going on. It has poor natural drainage, and was originally in swamps or sloughs, but by means of artificial drainage, it has been completely reclaimed. Altho the soil is fine-grained, it drains well, having a large number of checks, or joints, which make it quite permeable to water. The openings produced by worms and crayfish and deep-rooting plants have further increased this permeability.

The surface soil, 0 to 6⅔ inches, is a black clay loam, plastic and granular, varying locally to a black clayey silt loam where much silt has been

washed in covering the more clayey layer. It is very well supplied with organic matter, containing about 7 percent. A considerable percentage of sand, chiefly of the finer grades, may be found in this stratum.

The subsurface soil, 6⅔ to 18 or 20 inches, varies from a black to a brown clay loam, usually somewhat heavier than the surface stratum.

The subsoil, extending to a depth of 40 inches, is a dark drab, mottled or yellow clay loam, varying locally to a yellowish clayey silt. It frequently contains concretions of lime.

In the management of this type, the most important thing is to keep it in good tilth. To do this, thoro drainage is the first essential. Then it is necessary to use every means to maintain the supply of organic matter, for, it must be remembered, heavy clay soils become difficult to work in proportion as the organic matter is removed. Continued burning of corn stalks on this type of soil will finally result in great injury to its tilth and working condition.

Clover is especially beneficial to this black clay loam, as it loosens it up to a considerable depth and gives greater permeability to moisture and roots. However, it is not immediately necessary that so much clover or manure be plowed under on this type as on the brown silt loam.

As yet no field experiments have been conducted on black clay loam, but, where the soil contains sufficient limestone to respond to the test with strong acid, there is no need to add more, unless for physical improvement. No marked profit can be expected from adding phosphate, altho it will doubtless pay to keep the phosphorus content up to at least its present percentage.

Black Silt Loam (1125)

This type occupies low, flat areas of prairie land somewhat similar to those of the black clay loam (1120), but it has had more of the coarser material washed in, and as a result is somewhat friable. It covers a total area of 17.39 square miles, or 11,129 acres, comprising about 1.5 percent of the entire area of the county. In topography this type is flat and poorly drained naturally.

The surface soil, 0 to 6⅔ inches, is a black silt loam varying on the one hand to brown silt loam, and on the other to black clay loam. It is very granular and pervious to water. The organic-matter content is about 6.4 percent, or 64 tons per acre.

The subsurface, 6⅔ to 20 inches or more, is a black to dark brown clayey silt loam quite pervious to water. It contains 2.27 percent of organic matter, or 45 tons per acre.

The subsoil is a yellow or drabbish yellow slightly clayey silt that allows free movement of water.

In the management of this black silt loam, the same precautions should be observed as in that of black clay loam (1120). The black silt loam contains less clay and more silt and limestone than the black clay loam, but otherwise the two types are very much alike in composition and requirements.

Brown Sandy Loam (1160)

A small area of about 13 acres of rather coarse brown sandy loam occurs in Section 27, Township 36 North, Range 2 East, that does not differ greatly in fertility from the brown silt loam around it. This is the only area of this type in the county.

Since this type is somewhat sour in all strata to a depth of 40 inches, the use of 2 to 5 tons per acre of ground limestone should prove profitable, especially for the production of alfalfa or of clover in crop rotation. For a sandy loam, it is well supplied with phosphorus, considering the deep-feeding range afforded to plant roots; but legume crops should have a prominent place in the crop rotation and the nitrogen should be maintained by organic manures.

(b) UPLAND TIMBER SOILS

The upland timber soils differ from the prairie soils principally in the fact that they contain less organic matter. This low organic-matter content produces another striking difference, that of color, the prairie soils being black or brown, while the timber soils are yellow or gray.

Yellow-Gray Silt Loam (1134, *or* 934 *when found on morainal ridges*)

This type covers 94.56 square miles (60,518 acres) or 8.17 percent of the entire area of the county. It is located almost without exception on the upland along the larger streams, and comprises the less rolling areas that have been forested. The natural drainage systems have been better developed in this type than in any other except the yellow silt loam (1135).

The surface 6⅔ inches is a gray, yellowish gray, or brownish gray silt loam, the color varying with the topography; the nearly level areas usually are either lighter or darker in color, while the more rolling parts have more of a yellow or brownish yellow color. The organic-matter content also varies with the topography and with the length of time in forest as indicated by the character of the trees, but it averages 2.8 percent, or 28 tons per acre 6⅔ inches deep.

The subsurface soil, 6⅔ to 12 or 18 inches, is usually a gray to grayish yellow silt loam. The thickness of this stratum varies with the topography, being thinner on the more rolling areas. The amount of organic matter present is about 21 tons for 4 million pounds of soil.

The subsoil, extending to a depth of 40 inches, is a somewhat plastic yellow or grayish yellow clayey silt, the lower part sometimes reaching the glacial drift. This is due to the removal by erosion of a large part of the loessial material. This glacial drift may be locally a very gravelly deposit, but usually it is a gravelly clay that may be lacking in permeability. Otherwise each stratum of this type is quite pervious to water, with the exception of the level gray areas, where a tight, more or less compact clayey layer has formed. This occurs only in areas too small to be shown on the map.

This type is low in organic matter, and one of the first considerations for physical improvement is the problem of how to increase this constituent. It is scarcely possible under the present system of cropping even to maintain the supply of organic matter, much less to increase it. Crop residues must be turned back either directly or in manure, the corn stalks must be cut up and turned under instead of being burned, straw should be returned, clover grown and turned under, and pasture may be used to good advantage. Erosion should be prevented as much as possible, not only on this type, but on all others as well. Soils rich in organic matter are much less likely to erode because of the effect of the organic matter on permeability and granulation.

Aside from its low content of organic matter, this soil has a very good physical composition. It has a good topography, and affords excellent conditions for drainage. After the brown silt loam, it is by far the most im-

portant type of soil in the county. It occupies 60,000 acres of land, or five times as much as any less extensive all-tillable type.

On the whole, the yellow-gray silt loam offers one of the best opportunities for profitable soil improvement, and its improvement is more a matter of procedure than of experiment. The soil is normal in general character, and its chemical composition plainly reveals what is required for improvement; namely, limestone, nitrogenous organic matter, and phosphorus.

This type is acid in the surface, more acid in the subsurface, and still more acid in the subsoil.[1] An application of about 2 tons of limestone and half a ton of fine-ground rock phosphate every four years, with plenty of clover and crop residues or farm manure, will gradually work improvement; and, if one is prepared to make the investment, the initial applications may well be 5 tons of limestone and even 3 or 4 tons of phosphate. With 38,580 pounds in the surface soil of an acre, the potassium problem is merely one of liberation, and with even slight erosion, which is certain to occur where the surface drainage is good, the gradual renewal from the still greater abundance in the subsurface and subsoil insures a permanent supply of potassium for rational systems of either grain farming or live-stock farming. In comparison, analysis reveals only 1,033 pounds of total phosphorus in the surface soil of an acre and a still lower proportionate amount in the subsurface.

For definite results from the most practical field experiments upon typical yellow-gray silt loam, we must go down into "Egypt," where the people of Saline county, especially those in the vicinity of Raleigh and Galatia, have provided the University with a very suitable tract of this type of soil for a permanent experiment field. Here, as an average of triplicate tests each year, the yield of corn on untreated land was 25.3 bushels in 1910, 23.6 bushels in 1911, and 22 bushels in 1912; while the corresponding averages from land treated with heavy applications of limestone and a limited amount of organic manures were 41.4 bushels in 1910, 41.3 bushels in 1911, and 50.1 bushels in 1912, the corn being grown on a different series of plots every year in a four-year rotation of wheat, corn, oats, and clover. About the same proportionate increases were produced in wheat and hay, and the effect on oats was also marked.

Owing to the low supply of organic matter and limestone, phosphorus produced no benefit, as an average, during the first two years, but with increasing supplies of organic matter the effect of phosphorus is seen in the 1912 crops. Of course, a single four-year rotation cannot be practiced in three years, and the full benefit of the system of rotation and soil treatment is not to be expected before the third or fourth four-year period.

While limestone is the material first needed for the economic improvement of the more acid soil of southern Illinois, with organic manures and phosphorus to follow in order, the less acid soils of the central and northern parts of the state are frequently most deficient, relatively, in phosphorus and organic matter.

Table 8 shows in detail eleven years' results secured from the Antioch soil experiment field located in Lake county on the yellow-gray silt loam of the late Wisconsin glaciation. In acidity, this type in La Salle county is intermediate between the similar soils in Saline and Lake counties, but no experiment field has been conducted on this important soil type in the early Wisconsin glaciation.

[1]In one set of soil samples, limestone was found in the lower stratum, but this is unusual (as when till is found within 40 inches) and it was not included in the average.

TABLE 8.—CROP YIELDS IN SOIL EXPERIMENTS, ANTIOCH FIELD

Yellow-gray silt loam, undulating timberland; late Wisconsin glaciation		Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912
Plot	Soil treatment applied	Bushels per acre										
101	None[1]	44.8	36.6	17.8	18.5	35.9	12.4	65.6	12.2	5.2	34.4	21.3
102	Lime	45.1	38.9	12.8	10.3	31.5	9.5	61.6	11.7	3.0	24.6	17.5
103	Lime, nitrogen	46.3	40.8	2.8	17.8	37.8	6.4	60.3	13.0	1.4	10.4	24.4
104	Lime, phosphorus	50.1	53.6	12.5	35.8	57.4	13.4	70.9	23.3	6.8	37.4	49.1
105	Lime, potassium	48.2	50.2	9.7	21.7	34.9	12.9	62.5	13.5	4.6	20.4	18.8
106	Lime, nitro., phos.	56.6	62.7	15.9	15.2	59.3	20.9	49.1	33.8	6.0	37.0	46.9
107	Lime, nitro., potas.	52.1	54.9	10 3	11.8	39.0	11.1	52.6	21.0	1.6	7.0	16.9
108	Lime, phos., potas.	60.7	66.0	19.7	28.7	59.1	18.3	59.4	26.2	3.2	42.2	35.9
109	Lime, nitro., phos. potas.	61.2	69.1	31.9	18.0	65.9	31.4	51.9	30.5	3.0	44.2	31.9
110	Nitro., phos., potas.	59.7	71.8	37.2	16.3	66.3	28.8	55.9	34.5	4.0	49.0	38.1

Average Increase: Bushels per Acre

For nitrogen	3.0	4.7	1.6	−8.4	4.8	3.9	−10.1	5.9	−1.4	−6.5	−.3
For phosphorus	9.2	16.7	11.1	9.0	24.6	11.0	−1.4	13.7	2.1	24.6	21.6
For potassium	6.0	11.0	6.9	.3	3.2	5.9	−3.9	2.3	−1.2	1.1	−8.6
For nitro., phos. over phos.	6.5	9.1	3.4	−20.6	1.9	7.5	−21.8	10.5	−.8	−.4	2.2
For phos., nitro. over nitro.	10.3	21.9	13.1	−2.6	21.5	14.5	−11.2	20.8	4.6	26.6	22.5
For potas., nitro., phos. over nitro., phos.	4.6	6.4	16.0	2.8	6.6	10.5	2.8	−3.3	−3.0	7.2	−15.0

Value of Crops per Acre in Eleven Years

Plot	Soil treatment applied	Total value of eleven crops	Value of increase
101	None	$112.16	
102	Lime	96.38	$−15.78
103	Lime, nitrogen	97.89	−14.27
104	Lime, phosphorus	157.67	45.51
105	Lime, potassium	111.86	−.30
106	Lime, nitrogen, phosphorus	152.75	40.59
107	Lime, nitrogen, potassium	104.89	−7.27
108	Lime, phosphorus, potassium	160.25	48.09
109	Lime, nitrogen, phosphorus, potassium	164.83	52.67
110	Nitrogen, phosphorus, potassium	172.78	60.62

Average Value of Increase per Acre in Eleven Years		Cost of increase
For nitrogen	$−1.45	$165.00
For phosphorus	56.12	27.50
For potassium	9.28	27.50
For nitrogen and phosphorus over phosphorus	−4.92	165.00
For phosphorus and nitrogen over nitrogen	54.86	27.50
For potassium, nitrogen, and phosphorus over nitrogen and phosphorus	12.08	27.50

[1]Plot 101, the check plot, is the lowest ground but it is well drained and is appreciably better land than the rest of the field. Plot 102 is a more trustworthy check plot.

The Antioch field was started in order to learn as quickly as possible just what effect would be produced by the addition of nitrogen, phosphorus, and potassium, singly and in combination. These elements have all been added in commercial form. Only a small amount of lime was applied at the beginning, and with the abnormality of Plot 1 and with an abundance of limestone in the subsoil (a common condition in the late Wisconsin glaciation), no conclusions can be drawn regarding the effect of lime.

As an average of 44 tests (4 each year for 11 years), liberal applications of commercial nitrogen produced a slight decrease in crop values, phosphorus paid back 200 percent of its cost, while each dollar invested in potassium brought back only 34 cents (a net loss of 66 percent). Thus, while the detailed data show great variation, owing both to some irregularity of soil and to some very abnormal seasons, with three almost complete crop failures (1904, 1907, and 1910), yet the general summary strongly confirms the analytical data in showing the need of applying phosphorus and the profit from its use, and the loss in adding potassium. In most cases commercial nitrogen damaged the small grains by causing the crop to lodge; but whenever a corn yield of 40 bushels or more was secured where phosphorus was applied either alone or with potassium, then the addition of nitrogen produced an increase. From a comparison of the results from the Sibley and Bloomington fields, we must conclude that better yields are to be secured by providing nitrogen thru the growing of legume crops in the rotation rather than by the use of commercial nitrogen, which is evidently too readily available, causing too rapid growth and consequently weakness of straw; and of course the most economic source of nitrogen, where that element is needed for soil improvement in general farming, is the atmosphere. (See Appendix for detailed discussion of "Permanent Soil Improvement.")

Yellow Silt Loam (1135 *or* 935)

This type, like the preceding, is found principally along the large streams, but it also includes other hilly and broken land unsuited for ordinary agriculture. It comprises 41.12 square miles, or 26,317 acres, and constitutes 3.55 percent of the total area of the county. The development of natural drainage channels has been carried to excess, and altho perfectly surface-drained this land has been spoiled by nature for many agricultural purposes.

The surface soil, 0 to 6⅔ inches, is a yellow silt loam varying to a grayish yellow. The freshly plowed soil appears yellow or brownish yellow, but when it becomes dry after a rain it is of a grayish color. The organic-matter content is quite low, averaging only 2.05 percent, or 20½ tons in the plowed soil of an acre.

The subsurface varies from a yellow silt loam to a yellow clayey silt loam, and contains only about 15 tons of organic matter per acre of 4 million pounds, the amount diminishing with depth. The thickness of this stratum varies from 2 to 12 inches, depending on the amount of recent erosion.

The subsoil consists of a yellow clayey silt.

Owing to erosion, this type varies greatly. Glacial drift is frequently exposed on the surface. In some cases it forms both subsurface and subsoil, while in others it constitutes all or part of the subsoil, or it may even be found only below 40 inches.

The first and most important thing in the management of this soil is to prevent erosion, which may occur either by sheet washing or by gullying.

On uniform slopes sheet washing does the greater damage, but on the irregular slopes found in this county both forms do great damage. Many of the slopes are too steep to permit of cultivation, and they ought not to be cleared of the protecting forest. Most of this type is in forest or pasture, and should never be cultivated, for, if broken up, erosion would shortly ruin the land for all purposes. (For methods of preventing erosion of soils see Circular 119.)

The only general soil treatment recommended for this type is the use of ground limestone either when preparing the land for seeding to legume crops or as a top-dressing on pastures to encourage the growth of clovers in the pasture herbage. Where the slope is not too steep, alfalfa may sometimes be grown to advantage. In getting this crop started, 500 pounds per acre of steamed bone meal or acid phosphate may well be plowed under with farm manure, and then 5 tons per acre of ground limestone should be applied before preparing the seed bed, which of course, ought to be well inoculated with soil from an old alfalfa field or sweet-clover patch. (See Circular 86, "Science and Sense in the Inoculation of Legumes.")

Rock Outcrop (1199)

This type consists of rock ledges and some uncovered rock surfaces, principally in the Illinois-river valley from Utica east. The rock is nearly all St. Peters sandstone, with some magnesian limestone in the vicinity of La Salle and Utica that is used for cement. A shaley sandstone is exposed in the Illinois-river valley near Seneca that gives rise to a residual type of soil in that region.

(c) TERRACE SOILS

These consist of soils formed on terraces, or benches, in valleys. The terraces owe their formation generally to the deposition of material from an overloaded stream during the melting of the glaciers. In this way valleys were partly filled. Later these streams cut down thru these fills and developed new bottom lands or flood plains at a lower level, leaving part of the old fill as a terrace. The lowest and most recently formed bottom land is called *first bottom*. The material filling the valleys may be coarse or fine. That forming the terraces in the Vermilion valley, Indian creek, and in part in the Illinois-river valley, is mostly silt, while in the Fox-river valley it is sand and gravel. Part of the terrace of the Illinois-river valley seems to be the stony floor of the valley covered from a few inches to several feet with fine material that now forms the soil. In many cases this material is partly of residual origin. (The series number for the terrace soils is 1500.)

Brown Silt Loam (1526)

This type occurs only in the Illinois-river valley. Owing to its method of formation, it is somewhat variable. The material is derived both from sediment deposited by the Illinois river at a former period and by small streams from the upland. The older material is characterized by a much darker color and heavier texture, while the newer deposit brought down by small streams is usually lighter in color as well as coarser in texture. This type is not generally well drained, and in many areas thoro drainage is the first essential. As a rule, it lies sufficiently above the Illinois river to allow of good drainage.

The total area of this type is 10.26 square miles, or 6,566 acres, and comprises .88 percent of the entire area of the county.

The surface soil, 0 to 6⅔ inches, varies from a light brown silt loam to a dark brown clayey silt loam, the heavier phase predominating. Locally, even some black clay loam is found, also small areas of muck or shallow peat, with their characteristic surface soils, while in places the surface soil contains a considerable percentage of gravel. These local variations are in too small areas to be shown on the map.

The subsurface soil varies from a brown to a black silt loam or clay loam extending to a depth of from 16 to 25 inches.

The subsoil varies from a yellow plastic clayey silt to a drab clay, the latter usually occurring in the areas originally poorly drained.

The different strata of this type are sufficiently pervious to permit good drainage, and drainage is a matter of first importance. The organic matter should be maintained, and even increased in the lighter phases. The type is exceedingly rich in potassium and limestone (especially in the subsurface and subsoil), but the addition of phosphorus will be necessary if its productive power is to be maintained at a high point.

Brown Silt Loam on Gravel (1526.4)

The total area of this type in the county is 83.2 acres. As an average, the gravel is about 22 inches below the surface. This provides excellent drainage,—in fact, too good for seasons when the crop is likely to suffer from lack of moisture.

The surface soil, 0 to 6⅔ inches, is a brown silt loam containing a perceptible amount of sand.

The subsurface, 6⅔ to 16 or 18 inches, is a light brown silt loam becoming lighter with depth.

The subsoil is composed chiefly of gravel, but it may have some silty material overlying the gravel. The comparatively thin stratum of fine material does not furnish a sufficient reservoir for the moisture necessary for crop use unless rains are frequent.

While this type is not markedly acid, it is devoid of limestone even to a depth of 40 inches. Organic manures, phosphorus, and limestone are all required for the improvement and maintenance of its fertility.

Brown Silt Loam on Rock (1526.5)

This type occupies only 38.4 acres and lies in one area in the Illinois-river valley east of Ottawa. It is rather poorly drained. The surface soil is a brown to black slightly clayey silt loam, while the subsurface is somewhat heavier. On the whole, this is one of the richest soils found in Illinois. It is about twice as rich in nitrogen and four times as rich in phosphorus as the common corn-belt prairie land. The rocks, which are not always covered by the soil, consist of boulders and not bed rock, and consequently the subsoil may absorb and retain moisture fairly well. It is suggested that this area may once have been the roosting place for wild water fowls or other birds, and that the exceptional richness of the soil may be due to the accumulated droppings and decomposed feathers and skeletons of the birds. Much of the area can be used only for pasture because of the numerous boulders, many of which lie near the surface while some rise above it.

Brown Silt Loam over Gravel (1527)

This type aggregates 5.12 square miles, or 3,277 acres. It occurs in large areas along the Fox river and lies on part of the old gravel fill of that valley. As a rule, the type is well drained, owing to the pervious character of the subsoil. The topography is undulating, due to erosion and the action of wind in piling up silt and sand.

The surface soil, 0 to 6⅔ inches, is a brown silt loam, the color varying with the topography and drainage.

The subsurface soil, 6⅔ to 18 inches, is a light brown silt loam underlain by a yellow silt subsoil. Locally this type has a perceptible amount of sand.

This type is rich only in potassium, and requires for its improvement limestone, organic manures, and phosphorus.

Yellow-Gray Silt Loam on Gravel (1534.4)

A small area of this type, 12.8 acres, occurs in Sections 35 and 36, Township 35 North, Range 4 East. The surface soil is a light grayish yellow silt loam containing 2.5 percent of organic matter, while the subsurface soil contains .8 percent. Gravel occurs commonly at a depth of 18 to 24 inches.

The analysis shows the need of organic manures, phosphorus, and limestone.

Yellow-Gray Silt Loam over Gravel (1536)

This type is found to some extent along the larger streams, but especially along the Fox river. It covers a total area of 6.68 square miles, or 4,275 acres, a trifle over ½ percent of the total area of the county. The topography varies somewhat, erosion and wind action having produced a gently rolling or undulating surface.

The surface soil varies from a grayish yellow to a yellow silt loam. Sand in perceptible amounts is almost invariably present. The organic-matter content amounts to 2.5 percent, or 25 tons per acre.

The subsurface soil, 6⅔ to 16 inches, is a yellow to grayish yellow silt loam containing about .7 percent of organic matter.

The subsoil is a yellow pulverulent silt.

For a silt loam, this type is poor in organic matter and phosphorus, and it is acid even to a depth of 40 inches, so that, in addition to organic matter and phosphorus, limestone should be supplied.

Brown Sandy Loam (1560)

This type covers only 4.80 square miles, or 3,072 acres, and occurs entirely along the Fox and Illinois rivers. Its height above the river varies somewhat, being so low in some places as to be subject to overflow during extremely high water. It is generally well drained, altho in some small areas the difficulty of securing a proper outlet renders it too wet.

The surface soil, 0 to 6⅔ inches, is a brown sandy loam, the color varying with the drainage. The sand is mostly coarse. Much of it in the Illinois-river valley is probably derived from the sandstone in the immediate vicinity.

Owing to its physical composition, this type is easy to work and to keep in good tilth.

The subsurface soil, 6⅔ to about 20 inches, is a brown sandy loam, the color becoming lighter with depth. This is underlain with a yellow or brown-

ish yellow subsoil that varies from a sandy loam to a sand. In some cases this latter is probably residual sand. At lower depths gravel is sometimes found; indeed at Sheridan large quantities are being taken from this type of terrace soil.

Considering its deep feeding range, this sandy loam is well supplied with phosphorus. Limestone and organic manures are the materials most needed for its improvement, and it is not unlikely that potassium could be used with profit. While the total supply of potassium is large, most of it is locked up in medium or coarse sand grains. To obtain the best and most profitable results on such soils, the use of potassium is usually required, altho very marked improvement can be made with limestone and legume crops; and, if all coarse products are returned to the soil either directly or in manure, without loss by leaching, the necessity for purchasing potassium will be greatly reduced.

Brown Sandy Loam on Gravel (1560.4)

This type occupies an area of 192 acres in the valley of the Illinois river near Seneca. It is rather variable both as to the amount of sand it contains and the depth to the gravel beneath the surface.

The surface stratum, 0 to 6⅔ inches, is a brown sandy loam, with 2.2 percent organic matter, while the subsurface is lighter in color, containing 1.2 percent of organic matter. The depth to gravel varies from 12 to 30 inches.

This type is well supplied with phosphorus but is poor in organic matter and, altho nearly neutral, contains no limestone. The use of potassium in addition to limestone and organic manures may prove profitable, especially if much potassium is carried away in the products sold from the farm.

Brown Sandy Loam on Rock (1560.5)

This type occurs only in the Illinois-river valley and represents the rock of the old river bed that has become covered with sandy material either thru deposition from water or wind or thru disintegration of the underlying sandstone by weathering agencies. This material has become mixed with more or less organic matter, thus forming a soil. The area covered is 5.73 square miles, or 3,667 acres, a little less than ½ percent of the entire area of the county. The depth to the rock varies from 12 to 30 inches.

The surface soil, 0 to 6⅔ inches, is a brown sandy loam, with a variable quantity of sand and 4.55 percent, or 60 tons per acre, of organic matter.

The subsurface varies from a sandy loam to a sand, the latter being derived from the sandstone underlying it.

This type is not of great value agriculturally because of the proximity of the rock to the surface, which renders it a poor soil to resist either drouth or excessive rainfall, altho the crops suffer less from the latter than from the former. Much of it is not under cultivation. Liberal use should be made of legumes and organic manures; and both the physical and the chemical compositions indicate that potassium should be applied for the best results. The soil still contains a fair amount of humus and limestone; and, for a sandy loam, the phosphorus supply is very satisfactory, altho, where the depth of soil is too restricted, additional phosphorus may be needed if the improvement of such shallow soil is attempted. This, however, is scarcely to be ad-

vised, unless for special crops and with provision to supplement the rainfall by irrigation when necessary. The narrow ratio between the nitrogen and the organic carbon indicates that the organic matter consists largely of old plant residues resistant to decay.

Yellow-Gray Sandy Loam (1564)

This type covers less than 10 acres of land. The surface is a yellowish gray sandy loam. The soil is very poor in nitrogen and organic matter, and the supply of limestone is limited, the subsurface and subsoil being acid. Liberal use of these materials should effect enormous improvement; indeed with the deep feeding range afforded plants, and the amount of phosphorus and potassium in the lower strata, it is doubtful if anything more than limestone and organic manures can be used with profit in good systems of farming.

Dune Sand (1581)

This type occupies only 25 acres, a part of which is in the Fox-river valley and the rest in the Illinois-river valley south of the river and west of Ottawa. It has the characteristic dune topography. The surface soil is a slightly loamy sand, with less than 1 percent of organic matter, underlain by a uniformly yellowish sand of medium texture. Only limestone and organic manures are needed to markedly improve this soil, but for the highest and most profitable improvement potassium and phosphorus may also need to be supplied, and probably in the order named.

Gravelly Loam (1590)

This type occurs in the Illinois-river valley west of Ottawa on both sides of the river, the gravel north of the river being the coarser. It occupies an area of 300 acres, and is undulating in topography.

The surface soil, 0 to 6⅔ inches, is a mixture of gravel, sand, and a small amount of the finer constituents, together with 5.56 percent of organic matter, or 74 tons per acre.

The subsurface resembles the surface but contains less organic matter. The gravel becomes so large and abundant at a depth of 15 to 24 inches that sampling with the soil auger is impracticable.

This is a moderately rich soil and ought to grow alfalfa, grapes, or other crops that are adapted to the soil and topography. With a liberal use of legume crops or organic manure, potassium is the only addition likely to prove profitable, most of this element being locked up in the coarse sand and gravel.

(d) SWAMP AND BOTTOM-LAND SOILS

Deep Brown Silt Loam (1426)

The Illinois river below a point about halfway between Utica and La Salle has developed a wide, level flood-plain extending to the west side of the county, while the flood-plain to the eastward is narrower and less conspicuous and in some places absent entirely. The deposition of sediment on this overflowed land has formed the deep brown silt loam of the bottom land. As a rule, it is low and rather poorly drained, with flat to slightly undulating topography.

The surface soil, 0 to 6⅔ inches, is a brown, somewhat-clayey silt loam

containing 4.42 percent of organic matter, or 44 tons per acre. It varies somewhat from this composition, in places being sufficiently sandy to modify the texture to a considerable extent.

The subsurface and subsoil vary but little from the surface, containing 4.27 percent and 4 percent, respectively, of organic matter.

This is a rich, deep soil, and its fertility is usually well maintained by the sediments deposited from overflow, including some sewage received from the city of Chicago. It is exceedingly fertile, and crops grow upon it with remarkable rapidity.

A thoroly adequate system of underdrainage which will quickly remove the surplus soil water would be of great assistance in getting the land into condition for planting as soon as possible after the usual spring overflow. It is by no means certain, however, that permanent protection from overflow with its usual enriching deposit, would result in a larger aggregate of crops produced during a long series of years, provided the normal level of the water is not too near the surface of the land.

Deep Peat (1401)

This type is found exclusively in the Illinois-river valley, with the exception of a small area in Section 27, east of Tonica, and occupies a total area of 364 acres. The peat in the Illinois valley is found generally in the lower and more poorly drained areas near the bluff and where the land receives water either from springs or from surface drainage from higher land. This has brought about conditions favorable for the growth and preservation of peat-forming grasses, sedges, and mosses, whose partly-decayed products have accumulated until a deposit of peat 30 inches or more in depth has formed. Much of this is still a swamp and is utilized, if at all, only for hay.

Owing to the origin of this type, there is generally not much difference between the strata.

The surface soil, 0 to 6⅔ inches, is a brown peat varying somewhat in the different areas on account of the amount of decomposition from overflow. The one composite sample collected from this stratum contained 30.6 percent of organic matter, but in some areas the amount is doubtless still higher.

The subsurface soil is a brown, undecomposed peat, showing 47.12 percent of organic matter in the sample collected. The subsoil changes but little to a depth of 40 inches.

Drainage is the first requirement of this type. A trial application of potassium is recommended; and, with continued cropping, applications of phosphorus may also become profitable. (See Illinois Bulletin 157, "Peaty Swamp Lands.")

Medium Peat on Clay (1402)

This type is represented by an area of about 83 acres east of Tonica in Section 27. It occupies a depression in the center of which is an area of deep peat with the medium peat surrounding it. This area has been drained and is under cultivation.

The surface stratum, 0 to 6⅔ inches, is a dark brown peat containing 36.1 percent of organic matter so thoroly decomposed as to have lost all traces of vegetable tissue.

The subsurface is a black, decomposed peat lying upon a drab clay 16 to 20 inches below the surface.

If this soil does not produce good crops when well drained, the remedy is likely to be found in deep plowing. If necessary, one plow should follow another in the same furrow in order to reach the clay (which is rich in potassium) and mix it with the more peaty top soil, as more fully explained in Bulletin 157.

(e) RESIDUAL SOILS

This class of soils is formed by the accumulation of the loose material resulting from the weathering of rocks in place. Very little of this class exists in Illinois, owing to the action of the glaciers in removing and covering up the residual material by glacial drift, or boulder clay. La Salle county probably has the largest area of residual soil found in the state.

Brown Sandy Loam on Rock (060.5)

This type covers 2.38 square miles, or 1523 acres. It is formed from the disintegration of a shaly sandstone, and is found only in the valley of the Illinois river where the drift has been removed by the stream. The process of disintegration has produced from 12 to 30 inches of loose material which forms the soil.

The surface soil, 0 to 6⅔ inches, is a light brown sandy loam varying to a yellowish brown. It contains many small pieces of the shaly sandstone, usually not over an inch or two in diameter and ½ inch thick. It contains 2.27 percent of organic matter, or 30 tons per acre.

The subsurface soil is a yellow to brownish yellow sandy loam. Rock is found 12 to 30 inches below the surface. The proximity of the rock to the surface makes the crops growing on this type very subject to drouth or to excessive moisture. Drainage is at once very essential and extremely difficult.

This type is poor in organic matter and contains no limestone; both these materials should be provided for its improvement. Considering its shallow character and coarse texture, we may expect that both phosphorus and potassium will be required for its most marked improvement, and irrigation may also be needed; but so much expense as this would entail is justified only for intensive cropping.

Residual Sand (083)

This type is formed from the disintegration of the St. Peters sandstone and has no particular agricultural value. None of it is under cultivation, but it carries a rather stunted growth of timber. The type covers 70 acres and, in addition, some small areas along the bluffs of the Illinois river not large enough to map. The surface for about 2 inches is a slightly loamy sand and then passes into a yellow sand which continues to within a few inches of the sand rock, where a white sand is encountered. The topography is very rolling.

In plant-food content this residual sand is the poorest soil thus far found in Illinois. While the top soil was found to contain about 2 tons of limestone per acre, this was evidently due to some surface addition, for the subsurface and subsoil contain no lime.

To produce satisfactory crops upon this soil, liberal use should be made of organic manures, phosphorus, potassium, and dolomitic limestone, the latter supplying calcium and magnesium. Provision should also be made for irrigation as a means of protection during even short periods of drouth, especially where the bed rock is only 2 or 3 feet below the surface. Such complete treatment would not be practical except possibly in gardening.

APPENDIX

A study of the soil map and the tabular statements concerning crop requirements, the plant-food content of the different soil types, and the actual results secured from definite field trials with different methods or systems of soil improvement, and a careful study of the discussion of general principles and of the descriptions of individual soil types, will furnish the most necessary and useful information for the practical improvement and permanent preservation of the productive power of every kind of soil on every farm in the county.

More complete information concerning the most extensive and important soil types in the great soil areas in all parts of Illinois is contained in Bulletin 123, "The Fertility in Illinois Soils," which contains a colored general survey soil map of the entire state.

Other publications of general interest are:

Bulletin No. 76, "Alfalfa on Illinois Soils"
Bulletin No. 94, "Nitrogen Bacteria and Legumes"
Bulletin No. 115, "Soil Improvement for the Worn Hill Lands of Illinois"
Bulletin No. 125, "Thirty Years of Crop Rotation on the Common Prairie Lands of Illinois"
Circular No. 110, "Ground Limestone for Acid Soils"
Circular No. 127, "Shall we use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils?"
Circular No. 129, "The Use of Commercial Fertilizers"
Circular No. 149, "Some Results of Scientific Soil Treatment" and "Methods and Results of Ten Years' Soil Investigation in Illinois"
Circular No. 165, "Shall we use 'Complete' Commercial Fertilizers in the Corn Belt?"

NOTE.—Information as to where to obtain limestone, phosphate, bone meal, and potassium salts, methods of application, etc., will also be found in Circulars 110 and 165.

SOIL SURVEY METHODS

The detail soil survey of a county consists essentially of indicating on a map the location and extent of the different soil types; and, since the value of the survey depends upon its accuracy, every reasonable means is employed to make it trustworthy. To accomplish this object three things are essential: first, careful, well-trained men to do the work; second, an accurate base map upon which to show the results of their work; and, third, the means necessary to enable the men to place the soil-type boundaries, streams, etc., accurately upon the map.

The men selected for the work must be able to keep their location exactly and to recognize the different soil types, with their principal variations and limits, and they must show these upon the maps correctly. A definite system is employed in checking up this work. As an illustration, one soil expert will survey and map a strip 80 rods or 160 rods wide and any convenient length, while his associate will work independently on another strip adjoining this area, and, if the work is correctly done, the soil type boundaries will match up on the line between the two strips.

An accurate base map for field use is absolutely necessary for soil mapping. The base maps are made on a scale of one inch to the mile. The official data of the original or subsequent land survey are used as a basis in the construction of these maps, while the most trustworthy county map available is used in locating temporarily the streams, roads, and railroads. Since the best of these published maps have some inaccuracies, the location of every road, stream, and railroad must be verified by the soil surveyors, and cor-

rected if wrongly located. In order to make these verifications and corrections, each survey party is provided with an odometer for measuring distances, and a plane table for determining directions of roads, railroads, etc.

Each surveyor is provided with a base map of the proper scale, which is carried with him in the field; and the soil-type boundaries, additional streams, and necessary corrections are placed in their proper locations upon the map while the mapper is on the area. Each section, or square mile, is divided into 40-acre plots on the map, and the surveyor must inspect every ten acres and determine the type or types of soil composing it. The different types are indicated on the map by different colors, pencils being carried in the field for this purpose.

A small auger 40 inches long forms for each man an invaluable tool with which he can quickly secure samples of the different strata for inspection. An extension for making the auger 80 inches long is taken by each party, so that any peculiarity of the deeper subsoil layers may be studied. Each man carries a compass to aid in keeping directions. Distances along roads are measured by an odometer attached to the axle of the vehicle, while distances in the field off the roads are determined by pacing, an art in which the men become expert by practice. The soil boundaries can thus be located with as high a degree of accuracy as can be indicated by pencil on the scale of one inch to the mile.

Soil Characteristics

The unit in the soil survey is the soil type, and each type possesses more or less definite characteristics. The line of separation between adjoining types is usually distinct, but sometimes one type grades into another so gradually that it is very difficult to draw the line between them. In such exceptional cases, some slight variation in the location of soil-type boundaries is unavoidable.

Several factors must be taken into account in establishing soil types. These are (1) the geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial, or cumulose; (2) the topography, or lay of the land; (3) the native vegetation, as forest or prairie grasses; (4) the structure, or the depth and character of the surface, subsurface, and subsoil; (5) the physical, or mechanical, composition of the different strata composing the soil, as the percentages of gravel, sand, silt, clay, and organic matter which they contain; (6) the texture, or porosity, granulation, friability, plasticity, etc.; (7) the color of the strata; (8) the natural drainage; (9) agricultural value, based upon its natural productiveness; (10) the ultimate chemical composition and reaction.

The common soil constituents are indicated in the following outline:

Constituents of Soils

Soil Constituents	Organic Matter	Comprising undecomposed and partially decayed vegetable material	
	Inorganic Matter	Clay	.001 mm.[1] and less
		Silt	.001 mm. to .03 mm.
		Sand	.03 mm. to 1. mm.
		Gravel	1. mm. to 32 mm.
		Stones	32. mm. and over

[1]25 millimeters equal 1 inch.

Further discussion of these constituents is given in Circular 82.

GROUPS OF SOIL TYPES

The following gives the different general groups of soils:

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or silt.

Peaty loams—15 to 35 percent of organic matter mixed with much sand and silt and a little clay.

Mucks—15 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 25 percent of clay, usually mixed with much silt.

Clay loams—Soils with from 15 to 25 percent of clay, usually mixed with much silt and some sand.

Silt loams—Soils with more than 50 percent of silt and less than 15 percent of clay, mixed with some sand.

Loams—Soils with from 30 to 50 percent of sand mixed with much silt and a little clay.

Sandy loams—Soils with from 50 to 75 percent of sand.

Fine sandy loams—Soils with from 50 to 75 percent of fine sand mixed with much silt and little clay.

Sands—Soils with more than 75 percent of sand.

Gravelly loams—Soils with 15 to 50 percent of gravel with much sand and some silt.

Gravels—Soils with more than 50 percent of gravel.

Stony loams—Soils containing a considerable number of stones over one inch in diameter.

Rock outcrop—Usually ledges of rock having no agricultural value.

More or less organic matter is found in nearly all the above classes.

SUPPLY AND LIBERATION OF PLANT FOOD

The productive capacity of land in humid sections depends almost wholly upon the power of the soil to feed the crop; and this, in turn, depends both upon the stock of plant food contained in the soil and upon the rate at which this is liberated, or rendered soluble and available for use in plant growth. Protection from weeds, insects, and fungous diseases, tho exceedingly important, is not a positive but a negative factor in crop production.

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but the rate of liberation is governed by many factors, some of which may be controlled by the farmer, while others are largely beyond his control. Chief among the important controllable factors which influence the liberation of plant food are limestone and decaying organic matter, which may be added to the soil by direct application of ground limestone and farm manure. Organic matter may be supplied also by green-manure crops and crop residues, such as clover, cowpeas, straw, and cornstalks. The rate of decay of organic matter depends largely upon its age and origin, and it may be hastened by tillage. The chemical analysis shows correctly the total organic carbon, which represents, as a rule, but little more than half the organic matter; so that 20,000 pounds of organic carbon in the plowed soil of an acre correspond to nearly

20 tons of organic matter. But this organic matter consists largely of the old organic residues that have accumulated during the past centuries because they were resistant to decay, and 2 tons of clover or cowpeas plowed under may have greater power to liberate plant food than the 20 tons of old, inactive organic matter. The recent history of the individual farm or field must be depended upon for information concerning recent additions of active organic matter, whether in applications of farm manure, in legume crops, or in grass-root sods of old pastures.

Probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that with the normal rainfall of Illinois the productive power of the land depends primarily upon the stock of plant food contained in the soil and upon the rate at which it is liberated, just as the success of the merchant depends primarily upon his stock of goods and the rapidity of sales. In both cases the stock of any commodity must be increased or renewed whenever the supply of such commodity becomes so depleted as to limit the success of the business, whether on the farm or in the store.

As the organic matter decays, certain decomposition products are formed, including much carbonic acid, some nitric acid, and various organic acids, and these have power to act upon the soil and dissolve the essential mineral plant foods, thus furnishing soluble phosphates, nitrates, and other salts of potassium, magnesium, calcium, etc., for the use of the growing crop.

As already explained, fresh organic matter decomposes much more rapidly than the old humus, which represents the organic residues most resistant to decay and which consequently has accumulated in the soil during the past centuries. The decay of this old humus can be hastened both by tillage, which maintains a porous condition and thus permits the oxygen of the air to enter the soil more freely and to effect the more rapid oxidation of the organic matter, and also by incorporating with the old, resistant residues some fresh organic matter, such as farm manure, clover roots, etc., which decay rapidly and thus furnish or liberate organic matter and inorganic food for bacteria, the bacteria, under such favorable conditions, appearing to have power to attack and decompose the old humus. It is probably for this reason that peat, a very inactive and inefficient fertilizer when used by itself, becomes much more effective when incorporated with fresh farm manure; so that, when used together, two tons of the mixture may be worth as much as two tons of manure, but if applied separately, the peat has little value. Bacterial action is also promoted by the presence of limestone.

The condition of the organic matter of the soil is indicated more or less definitely by the ratio of carbon to nitrogen. As an average, the fresh organic matter incorporated with soils contains about twenty times as much carbon as nitrogen, but the carbohydrates ferment and decompose much more rapidly than the nitrogenous matter; and the old resistant organic residues, such as are found in normal subsoils, commonly contain only five or six times as much carbon as nitrogen. Soils of normal physical composition, such as loam, clay loam, silt loam, and fine sandy loam, when in good productive

condition, contain about twelve to fourteen times as much carbon as nitrogen in the surface soil; while in old, worn soils that are greatly in need of fresh, active, organic manures, the ratio is narrower, sometimes falling below ten of carbon to one of nitrogen. (Except in newly made alluvial soils, the ratio is usually narrower in the subsurface and subsoil than in the surface stratum.)

It should be kept in mind that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all agricultural plants, only one (hydrogen) from water, and seven from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes), in case the amount liberated from the soil is insufficient; but even these plants (which include only the clovers, peas, beans, and vetches, among our common agricultural plants) secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron and sulfur), and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Plants are made of plant-food elements in just the same sense that a building is made of wood and iron, brick, stone, and mortar. Without materials, nothing material can be made. The normal temperature, sunshine, rainfall, and length of season in central Illinois are sufficient to produce 50 bushels of wheat per acre, 100 bushels of corn, 100 bushels of oats, and 4 tons of clover hay; and, where the land is properly drained and properly tilled, such crops would frequently be secured *if the plant foods were present in sufficient amounts and liberated at a sufficiently rapid rate to meet the absolute needs of the crops.*

CROP REQUIREMENTS

The accompanying table shows the requirements of such crops for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally in sufficient abundance compared with the amounts needed by plants, so that they are not known ever to limit the yield of general farm crops grown under normal conditions.)

TABLE A.—PLANT FOOD IN WHEAT, CORN, OATS, AND CLOVER

Produce		Nitrogen, pounds	Phosphorus, pounds	Potassium, pounds	Magnesium, pounds	Calcium, pounds
Kind	Amount					
Wheat, grain	50 bu.	71	12	13	4	1
Wheat straw	2½ tons	25	4	45	4	10
Corn, grain	100 bu.	100	17	19	7	1
Corn stover	3 tons	48	6	52	10	21
Corn cobs	½ ton	2		2		
Oats, grain	100 bu.	66	11	16	4	2
Oat straw	2½ tons	31	5	52	7	15
Clover seed	4 bu.	7	2	3	1	1
Clover hay	4 tons	160	20	120	31	117
Total in grain and seed		244[1]	42	51	16	4
Total in four crops		510[1]	77	322	68	168

[1]These amounts include the nitrogen contained in the clover seed or hay, which, however, may be secured from the air.

To be sure, these are large yields, but shall we try to make possible the production of yields only half or a quarter as large as these, or shall we set as our ideal this higher mark, and then approach it as nearly as possible with profit? Among the four crops, corn is the largest, with a total yield of more than six tons per acre; and yet the 100-bushel crop of corn is often produced on rich pieces of land in good seasons. In very practical and profitable systems of farming, the Illinois Experiment Station has produced, as an average of the six years 1905 to 1910, a yield of 87 bushels of corn per acre in grain farming (with limestone and phosphorus applied, and with crop residues and legume crops turned under), and 90 bushels per acre in live-stock farming (with limestone, phosphorus, and manure).

The importance of maintaining a rich surface soil cannot be too strongly emphasized. This is well illustrated by data from the Rothamsted Experiment Station, the oldest in the world. Thus on Broadbalk field, where wheat has been grown since 1844, the average yields for the ten years 1892 to 1901 were 12.3 bushels per acre on Plot 3 (unfertilized) and 31.8 bushels on Plot 7 (well fertilized), but the amounts of both nitrogen and phosphorus in the subsoil (9 to 27 inches) were distinctly greater in Plot 3 than in Plot 7, thus showing that the higher yields from Plot 7 were due to the fact that the plowed soil had been enriched. In 1893 Plot 7 contained per acre in the surface soil (0 to 9 inches) about 600 pounds more nitrogen and 900 pounds more phosphorus than Plot 3. Even a rich subsoil has little value if it lies beneath a worn-out surface.

METHODS OF LIBERATING PLANT FOOD

Limestone and decaying organic matter are the principal materials the farmer can utilize most profitably to bring about the liberation of plant food.

The limestone corrects the acidity of the soil and thus encourages the development not only of the nitrogen-gathering bacteria which live in the nodules on the roots of clover, cowpeas, and other legumes, but also the nitrifying bacteria, which have power to transform the insoluble and unavailable organic nitrogen into soluble and available nitrate nitrogen.

At the same time, the products of this decomposition have power to dissolve the minerals contained in the soil, such as potassium and magnesium, and also to dissolve the insoluble phosphate and limestone which may be applied in low-priced forms.

Tillage, or cultivation, also hastens the liberation of plant food by permitting the air to enter the soil and burn out the organic matter; but it should never be forgotten that tillage is wholly destructive, that it adds nothing whatever to the soil, but always leaves the soil poorer. Tillage should be practiced so far as is necessary to prepare a suitable seed-bed for root development and also for the purpose of killing weeds, but more than this is unnecessary and unprofitable in seasons of normal rainfall; and it is much better actually to enrich the soil by proper applications or additions, including limestone and organic matter (both of which have power to improve the physical condition as well as to liberate plant food) than merely to hasten soil depletion by means of excessive cultivation.

PERMANENT SOIL IMPROVEMENT

The best and most profitable methods for the permanent improvement of the common soils of Illinois are as follows:

(1) If the soil is acid, apply at least two tons per acre of ground limestone, preferably at times magnesian limestone ($CaCO_3MgCO_3$), which contains both calcium and magnesium and has slightly greater power to correct soil acidity, ton for ton, than the ordinary calcium limestone ($CaCO_3$); and continue to apply about two tons per acre of ground limestone every four or five years. On strongly acid soils, or in preparing the land for alfalfa, five tons per acre of ground limestone may well be used for the first application.

(2) Adopt a good rotation of crops, including a liberal use of legumes, and increase the organic matter of the soil either by plowing under the legume crops and other crop residues (straw and corn stalks), or by using for feed and bedding practically all the crops raised and returning the manure to the land with the least possible loss. No one can say in advance what will prove to be the best rotation of crops, because of variation in farms and farmers, and in prices for produce, but the following are suggested to serve as models or outlines:

First year, corn.
Second year, corn.
Third year, wheat or oats (with clover or clover and grass).
Fourth year, clover or clover and grass.
Fifth year, wheat and clover or grass and clover.
Sixth year, clover or clover and grass.

Of course there should be as many fields as there are years in the rotation. In grain farming, with small grain grown the third and fifth years, most of the coarse products should be returned to the soil, and the clover may be clipped and left on the land (only the clover seed being sold the fourth and sixth years); or, in live-stock farming, the field may be used three years for timothy and clover pasture and meadow if desired. The system may be reduced to a five-year rotation by cutting out either the second or the sixth year, and to a four-year system by omitting the fifth and sixth years.

With two years of corn, followed by oats with clover-seeding the third year, and by clover the fourth year, all produce can be used for feed and bedding if other land is available for permanent pasture. Alfalfa may be grown on a fifth field for four or eight years, which is to be alternated with one of the four; or the alfalfa may be moved every five years, and thus rotated over all five fields every twenty-five years.

Other four-year rotations more suitable for grain farming are:

Wheat (and clover), corn, oats, and clover; or corn (and clover), cowpeas, wheat, and clover. (Alfalfa may be grown on a fifth field and rotated every five years, the hay being sold.)

Good three-year rotations are:

Corn, oats, and clover; corn, wheat, and clover; or wheat (and clover), corn (and clover), and cowpeas, in which two cover crops and one regular crop of legumes are grown in three years.

A five-year rotation of (1) corn (and clover), (2) cowpeas, (3) wheat, (4) clover, and (5) wheat (and clover) allows legumes to be seeded four times, and alfalfa may be grown on a sixth field for five or six years in the combination rotation, alternating between two fields every five years, or rotating over all the fields if moved every six years.

To avoid clover sickness it may sometimes be necessary to substitute sweet clover or alsike for red clover in about every third rotation, and at the same

time to discontinue its use in the cover-crop mixture. If the corn crop is not too rank, cowpeas or soybeans may also be used as a cover crop (seeded at the last cultivation) in the southern part of the state, and, if necessary to avoid disease, these may well alternate in successive rotations.

For easy figuring it may well be kept in mind that the following amounts of nitrogen are required for the produce named:

1 bushel of oats (grain and straw) requires 1 pound of nitrogen.
1 bushel of corn (grain and stalks) requires 1½ pounds of nitrogen.
1 bushel of wheat (grain and straw) requires 2 pounds of nitrogen.
1 ton of timothy requires 24 pounds of nitrogen.
1 ton of clover contains 40 pounds of nitrogen.
1 ton of cowpeas contains 43 pounds of nitrogen.
1 ton of average manure contains 10 pounds of nitrogen.

The roots of clover contain about half as much nitrogen as the tops, and the roots of cowpeas contain about one-tenth as much as the tops.

Soils of moderate productive power will furnish as much nitrogen to clover (and two or three times as much to cowpeas) as will be left in the roots and stubble. For grain crops, such as wheat, corn, and oats, about two-thirds of the nitrogen is contained in the grain and one-third in the straw or stalks. (See also discussion of "The Potassium Problem," on pages below.)

(3) On all lands deficient in phosphorus (except on those susceptible to serious erosion by surface washing or gullying) apply that element in considerably larger amounts than are required to meet the actual needs of the crops desired to be produced. The abundant information thus far secured shows positively that fine-ground natural rock phosphate can be used successfully and very profitably, and clearly indicates that this material will be the most economical form of phosphorus to use in all ordinary systems of permanent, profitable soil improvement. The first application may well be one ton per acre, and subsequently about one-half ton per acre every four or five years should be applied, at least until the phosphorus content of the plowed soil reaches 2,000 pounds per acre, which may require a total application of from three to five or six tons per acre of raw phosphate containing 12½ percent of the element phosphorus.

Steamed bone meal and even acid phosphate may be used in emergencies, but it should always be kept in mind that phosphorus delivered in Illinois costs about 3 cents a pound in raw phosphate (direct from the mine in carload lots), but 10 cents a pound in steamed bone meal, and about 12 cents a pound in acid phosphate, both of which cost too much per ton to permit their common purchase by farmers in carload lots, which is not the case with limestone or raw phosphate.

Phosphorus once applied to the soil remains in it until removed in crops, unless carried away mechanically by soil erosion. (The loss by leaching is only about 1½ pounds per acre per annum, so that more than 150 years would be required to leach away the phosphorus applied in one ton of raw phosphate.)

The phosphate and limestone may be applied at any time during the rotation, but a good method is to apply the limestone after plowing and work it into the surface soil in preparing the seed bed for wheat, oats, rye, or barley, where clover is to be seeded; while phosphate is best plowed under with farm manure, clover, or other green manures, which serve to liberate the phosphorus.

(4) Until the supply of decaying organic matter has been made adequate, on the poorer types of upland timber and gray prairie soils some temporary benefit may be derived from the use of a soluble salt or mixture of salts, such as kainit, which contains both potassium and magnesium in soluble form and also some common salt (sodium chlorid). About 600 pounds per acre of kainit applied and turned under with the raw phosphate will help to dissolve the phosphorus as well as to furnish available potassium and magnesium, and for a few years such use of kainit will no doubt be profitable on lands deficient in organic matter, but the evidence thus far secured indicates that its use is not absolutely necessary and that it will not be profitable after adequate provision is made for decaying organic matter, since this will necessitate returning to the soil either all produce except the grain (in grain farming) or the manure produced in live-stock farming. (Where hay or straw is sold, manure should be bought.)

On soils which are subject to surface washing, including especially the yellow silt loam of the upland timber area, and to some extent the yellow-gray silt loam, and other more rolling areas, the supply of minerals in the subsurface and subsoil (which gradually renew the surface soil) tends to provide for a low-grade system of permanent agriculture if some use is made of legume plants, as in long rotations with much pasture, because both the minerals and nitrogen are thus provided in some amount almost permanently; but where such lands are farmed under such a system, not more than two or three grain crops should be grown during a period of ten or twelve years, the land being kept in pasture most of the time; and where the soil is acid a liberal use of limestone, as top-dressings if necessary, and occasional reseeding with clovers will benefit both the pasture and indirectly the grain crops.

Advantage of Crop Rotation and Permanent Systems

It should be noted that clover is not likely to be well infected with the clover bacteria during the first rotation on a given farm or field where it has not been grown before within recent years; but even a partial stand of clover the first time will probably provide a thousand times as many bacteria for the next clover crop as one could afford to apply in artificial inoculation, for a single root-tubercle may contain a million bacteria developed from one during the season's growth.

This is only one of several advantages of the second course of the rotation over the first course. Thus the mere practice of crop rotation is an advantage, especially in helping to rid the land of insects and foul grass and weeds. The deep-rooting clover crop is an advantage to subsequent crops because of that characteristic. The larger applications of organic manures (made possible by the larger crops) are a great advantage; and in systems of permanent soil improvement, such as are here advised and illustrated, more limestone and more phosphorus are provided than are needed for the meager or moderate crops produced during the first rotation, and consequently the crops in the second rotation have the advantage of such accumulated residues (well incorporated with the plowed soil) in addition to the regular applications made during the second rotation.

This means that these systems tend positively toward the making of richer lands. The ultimate analyses recorded in the tables give the absolute invoice of these Illinois soils. They show that most of them are positively deficient only in limestone, phosphorus, and nitrogenous organic matter: and

the accumulated information from careful and long-continued investigations in different parts of the United States clearly establishes the fact that in general farming these essentials can be supplied with greatest economy and profit by the use of ground natural limestone, very finely ground natural rock phosphate, and legume crops to be plowed under directly or in farm manure. On normal soils no other applications are absolutely necessary, but, as already explained, the addition of some soluble salt in the beginning of a system of improvement on some of these soils produces temporary benefit, and if some inexpensive salt, such as kainit, is used, it may produce sufficient increase to more than pay the added cost.

THE POTASSIUM PROBLEM

As reported in Illinois Bulletin 123, where wheat has been grown every year for more than half a century at Rothamsted, England, exactly the same increase was produced (5.6 bushels per acre), as an average of the first 24 years, whether potassium, magnesium, or sodium was applied, the rate of application per annum being 200 pounds of potassium sulfate and molecular equivalents of magnesium sulfate and sodium sulfate. As an average of 60 years (1852 to 1911), the yield of wheat has been 12.7 bushels on untreated land, 23.3 bushels where 86 pounds of nitrogen and 29 pounds of phosphorus per acre per annum were applied; and, as further additions, 85 pounds of potassium raised the yield to 31.3 bushels; 52 pounds of magnesium raised it to 29.2 bushels; and 50 pounds of sodium raised it to 29.5 bushels. Where potassium was applied, the average wheat crop removed 40 pounds of that element in the grain and straw, or three times as much as would be removed in the grain only for such crops as are suggested in Table A. The Rothamsted soil contained an abundance of limestone, but no organic matter was provided except the little in the stubble and roots of the wheat plants.

On another field at Rothamsted the average yield of barley for 60 years (1852 to 1911) has been 14.2 bushels on untreated land, 38.1 bushels where 43 pounds of nitrogen and 29 pounds of phosphorus have been applied per acre per annum; while the further addition of 85 pounds of potassium, 19 pounds of magnesium, and 14 pounds of sodium (all in sulfates) raised the average yield to 41.5 bushels, but, where only 70 pounds of sodium were applied in addition to the nitrogen and phosphorus, the average has been 43.0 bushels. Thus, as an average of 60 years, the use of sodium produced 1.8 bushels less wheat and 1.5 bushels more barley than the use of potassium, with both grain and straw removed and no organic manures returned.

In recent years the effect of potassium is becoming much more marked than that of sodium or magnesium, on the wheat crop; but this must be expected to occur in time where no potassium is returned in straw or manure, and no provision made for liberating potassium from the supply still remaining in the soil. If more than three-fourths of the potassium removed were returned in the straw (see Table A), and if the decomposition products of the straw have power to liberate additional amounts of potassium from the soil, the necessity of purchasing potassium in a good system of farming on such land is very remote.

While about half the potassium, nitrogen, and organic matter, and about one-fourth the phosphorus contained in manure will be lost by three or four months' exposure in the ordinary pile in the barn yard, there

is practically no loss if plenty of absorbent bedding is used on cement floors, and if the manure is hauled to the field and spread within a day or two after it is produced. Again, while the animals destroy two-thirds of the organic matter and retain one-fourth of the nitrogen and phosphorus in average live-stock farming, they retain less than one-tenth of the potassium, from the food consumed; so that the actual loss of potassium in the products sold from the farm, either in grain farming or in live-stock farming, is wholly negligible on land containing 25,000 pounds or more of potassium in the surface 6⅔ inches.

The removal of one inch of soil per century by surface washing (which is likely to occur wherever there is satisfactory surface drainage and frequent cultivation) would permanently maintain the potassium in grain farming by renewal from the subsoil, provided one-third of the potassium is removed by cropping before the soil is carried away.

From all of these facts it will be seen that the potassium problem is not one of addition but of liberation; and the Rothamsted records show that for many years other soluble salts have practically the same power as potassium to increase crop yields in the absence of sufficient decaying organic matter. Whether this action relates to supplying or liberating potassium for its own sake, or to the power of the soluble salt to increase the availability of phosphorus or other elements, is not known, but where much potassium is removed, as in the entire crops at Rothamsted, with no return of organic residues, probably the soluble salt functions in both ways.

As an average of 112 separate tests conducted in 1907, 1908, 1909, and 1910 on the Fairfield experiment field, an application of 200 pounds of potassium sulfate, containing 85 pounds of potassium and costing $5.10, increased the yield of corn by 9.3 bushels per acre; while 600 pounds of kainit, containing only 60 pounds of potassium and costing $4.00, gave an increase of 10.7 bushels. Thus, at 40 cents a bushel for corn, the kainit has paid for itself; but these results, like those at Rothamsted, were secured where no adequate provision had been made for decaying organic matter.

Additional experiments at Fairfield include an equally complete test with potassium sulfate and kainit on land to which 8 tons per acre of farm manure had been applied. As an average of 112 tests with each material, the 200 pounds of potassium sulfate increased the yield of corn by 1.7 bushels, while the 600 pounds of kainit also gave an increase of 1.7 bushels. Thus, where organic manure was supplied, very little effect was produced by the addition of either potassium sulfate or kainit; in part perhaps because the potassium removed in the crops is mostly returned in the manure if properly cared for, and perhaps in larger part because the decaying organic matter helps to liberate and hold in solution other plant-food elements, especially phosphorus.

In laboratory experiments at the Illinois Experiment Station, it has been shown that potassium salts and most other soluble salts increase the solubility of the phosphorus in soil and in rock phosphate as determined by chemical analysis; also that the addition of glucose with rock phosphate in pot-culture experiments increases the availability of the phosphorus, as measured by plant growth, altho the glucose consists only of carbon, hydrogen, and oxygen, and thus contains no plant food of value.

If we remember that, as an average, live stock destroy two-thirds of the organic matter of the food consumed, it is easy to determine from Table A

that more organic matter will be supplied in a proper grain system than in a strictly live-stock system; and the evidence thus far secured from older experiments at the University and at other places in the state indicates that if the corn stalks, straw, clover, etc., are incorporated with the soil as soon as practicable after they are produced (which can usually be done in the late fall or early spring), there is little or no difficulty in securing sufficient decomposition in our humid climate to avoid serious interference with the capillary movement of the soil moisture, a common danger from plowing under too much coarse manure of any kind in the late spring of a dry year.

If, however, the entire produce of the land is sold from the farm, as in hay farming, or when both grain and straw are sold, of course the draft on potassium will then be so great that in time it must be renewed by some sort of application. As a rule, such farmers ought to secure manure from town, since they furnish the bulk of the material out of which manure is produced.

CALCIUM AND MAGNESIUM

When measured by the actual crop requirements for plant food, magnesium and calcium are more limited in some Illinois soils than potassium. But with these elements we must also consider the loss by leaching. As an average of 90 analyses[1] of Illinois well-waters drawn chiefly from glacial sands, gravels, or till, 3 million pounds of water (about the average annual drainage per acre for Illinois) contained 11 pounds of potassium, 130 of magnesium, and 330 of calcium. These figures are very significant, and it may be stated that if the plowed soil is well supplied with the carbonates of magnesium and calcium, then a very considerable proportion of these amounts will be leached from that stratum. Thus the loss of calcium from the plowed soil of an acre at Rothamsted, England, where the soil contains plenty of limestone, has averaged more than 300 pounds a year as determined by analyzing the soil in 1865 and again in 1905. And practically the same amount of calcium was found by analyzing the Rothamsted drainage waters.

Common limestone, which is calcium carbonate ($CaCO_3$), contains, when pure, 40 percent of calcium, so that 800 pounds of limestone are equivalent to 320 pounds of calcium. Where 10 tons per acre of ground limestone were applied at Edgewood, Illinois, the average annual loss during the next ten years amounted to 790 pounds per acre. The definite data from careful investigations seem to be ample to justify the conclusion that where limestone is needed at least 2 tons per acre should be applied every 4 or 5 years.

It is of interest to note that thirty crops of clover of four tons each would require 3,510 pounds of calcium, while the most common prairie land of southern Illinois contains only 3,420 pounds of total calcium in the plowed soil of an acre. (See Soil Report No. 1.) Thus limestone has a positive value on some soils for the plant food which it supplies, in addition to its value in correcting soil acidity and in improving the physical condition of the soil. Ordinary limestone (abundant in the southern and western parts of the state) contains nearly 800 pounds of calcium per ton; while a good grade of dolomitic limestone (the more common limestone of northern Illinois) contains about 400 pounds of calcium and 300 pounds of magnesium per ton. Both of these elements are furnished in readily available form in ground dolomitic limestone.

[1]Reported by Doctor Bartow and associates, of the Illinois State Water Survey.

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

SOIL REPORT NO. 6

KNOX COUNTY SOILS

BY CYRIL G. HOPKINS, J. G. MOSIER,
J. H. PETTIT, AND J. E. READHIMER

URBANA, ILLINOIS, AUGUST, 1913

[1]On leave.

INTRODUCTORY NOTE

About two-thirds of Illinois lies in the corn belt, where most of the prairie lands are black or dark brown in color. In the southern third of the state, the prairie soils are largely of a gray color. This region is better known as the wheat belt, altho wheat is often grown in the corn belt and corn is also a common crop in the wheat belt.

Moultrie county, representing the corn belt; Clay county, which is fairly representative of the wheat belt; and Hardin county, which is taken to represent the unglaciated area of the extreme southern part of the state, were selected for the first Illinois Soil Reports by counties. While these three county soil reports were sent to the Station's entire mailing list within the state, Sangamon, La Salle, and other subsequent reports are sent only to the residents of the county concerned and to any one else upon request.

Each county report is intended to be as nearly complete in itself as it is practicable to make it, and, even at the expense of some repetition, each will contain a general discussion of important fundamental principles to help the farmer and landowner to understand the meaning of the soil fertility invoice for the lands in which he is interested. In Soil Report No. 1, "Clay County Soils," this discussion serves in part as an introduction, while in this and other reports it will be found in the Appendix, but if necessary it should be read and studied in advance of the report proper.

KNOX COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER, J. H. PETTIT, and J. E. READHIMER

Knox county lies in the upper Illinois glaciation and has an area of 720.69 square miles. The general topography of the northern and western half is undulating or slightly rolling, while the southern and southeastern portion is in part badly broken, especially along Spoon river and its tributaries. The upland prairie soils cover 57 percent of the county, the undulating timber lands about 14½ percent, the rough or rolling timber lands about 18½ percent, and the bottom lands nearly 10 percent.

The difference in topography is due to two causes—glacial action and stream erosion. Like most of the state, this county was covered by an ice sheet during the glacial period. During that time snow and ice accumulated in the region of Hudson Bay to such an amount that it pushed southward until a point was reached where the ice melted as rapidly as it advanced. In moving across the country, the ice gathered up all sorts and sizes of material, including pebbles, boulders, and even large masses of rock. Many of these were carried hundreds of miles and rubbed against the surface rocks or against each other until ground into powder. When the limit of advance was reached, where the ice largely melted, this material would accumulate in a broad undulating ridge, or moraine. When the ice melted away more rapidly than the glacier advanced, the terminus of the glacier would recede and leave a drift of boulder clay deposited somewhat uniformly, yet not entirely so, over the inter-morainal tract marking the area previously covered by the ice sheet. These intermorainal tracts are occupied chiefly by level, undulating, or rolling plains.

The material transported by the glacier varied with the character of the rocks over which it passed. Granites, limestones, sandstones, shales, etc., were mixed and ground up together. This mixture of all kinds of material, boulders, gravel, sand, silt, and clay, is called boulder clay, till, glacial drift, or simply drift. The grinding and denuding power of glaciers is enormous. A mass of ice 100 feet thick exerts a pressure of 40 pounds per square inch and this ice sheet may have been thousands of feet in thickness. The materials carried along in this mass of ice, especially the boulders and pebbles, became powerful agents for grinding and wearing away the surface over which the ice passed. Preglacial ridges and hills were rubbed down, valleys were filled with the debris, and the surface features changed entirely.

The depth of boulder clay over Knox county averages near 30 feet. No continuous morainal ridges occur; if they ever existed, they have been torn down thru erosion until now they are represented by a few high and somewhat isolated areas whose locations are shown upon the map by broken lines. These are also indicated by serial numbers 200 instead of 500. (See Bulletin 123, state map and pages 257 and 258.) There are two of these morainal areas in the county, one northwest and north of Oneida and the other south-

west of Yates City. This latter was probably at one time a continuous ridge, but it has been cut in two by Spoon river and Willow creek.

PHYSIOGRAPHY AND ALTITUDE

The northwest quarter of the county drains into the Mississippi river; the rest drains principally thru Spoon river into the Illinois. The divide between the two rivers extends south and southwest from Section 2, Township 13 North, Range 2 East of the Fourth Principal Meridian, leaving the county in the northwest corner of Township 10 North, Range 1 East. The altitude of the divide varies from 770 to 840 feet above sea level. The average altitude of the county is 725 feet. The highest point, 859 feet, is in Section 10, Township 13 North, Range 4 East, while the lowest, about 536 feet, is where Spoon river leaves the county.

Spoon river and its tributaries have produced quite a variation in topography. The valleys of these streams are from 50 to 200 feet or more below the general level of the upland. This has permitted the small streams entering the river to do a large amount of erosion, and as a result the land adjacent to the bottom land of the larger streams is cut up into hills and valleys unsuited for ordinary agriculture. Before the land was put under cultivation, forests had extended their way up the streams and were slowly invading the adjoining prairies.

SOIL MATERIAL AND SOIL TYPES

The Illinois glacier covered Knox county and left a thick mantle of drift, completely burying the old soil that preceded it. After this a long period elapsed during which a deep soil, known as the old Sangamon soil,[1] was formed on the Illinois drift. Later, other ice invasions occurred, but they covered only the northern and northeastern parts of the state. (See state map in Bulletin 123, Iowan and Wisconsin glaciations.) These ice sheets did not reach Knox county, but finely-ground rock (rock flour) in immense quantities was carried south by the waters from the melting ice and deposited on the flooded plains, where it was picked up by the wind, carried farther, and finally deposited upon the surface, burying the drift material of the Illinois glaciation and the old Sangamon soil to a depth of 5 to 50 feet or more. This wind-blown material, called loess, represents a mixture of all kinds of material over which the glacier passed. The deeper deposit is nearer and on the east side of the larger stream courses and opposite the greatest width of bottom land. Its average depth in this county is about 15 feet. Soil has been formed from this comparatively new material.

The soils of Knox county are divided into three classes, as follows:

(1) Upland prairie soils, rich in organic matter. These were originally covered with wild prairie grasses, the partially decayed roots of which have been the source of the organic matter. The flat prairie land contains the higher amount of this constituent because the grasses and roots grew more luxuriantly there and the higher moisture content largely preserved them from decay.

(2) Upland timber soils, including those zones along stream courses over which forests once extended. These soils contain much less organic matter

[1]The Sangamon soil may sometimes be seen in cuts as a somewhat dark or bluish sticky clay or a weathered zone of yellowish or brownish clay.

LEGEND

UPLAND PRAIRIE SOILS

26 526	Brown silt loam
20 520	Black clay loam
28 528	Brown-gray silt loam on tight clay

UPLAND TIMBER SOIL

34 534	Yellow-g
35 535	Yellow s
32 532	Light gr

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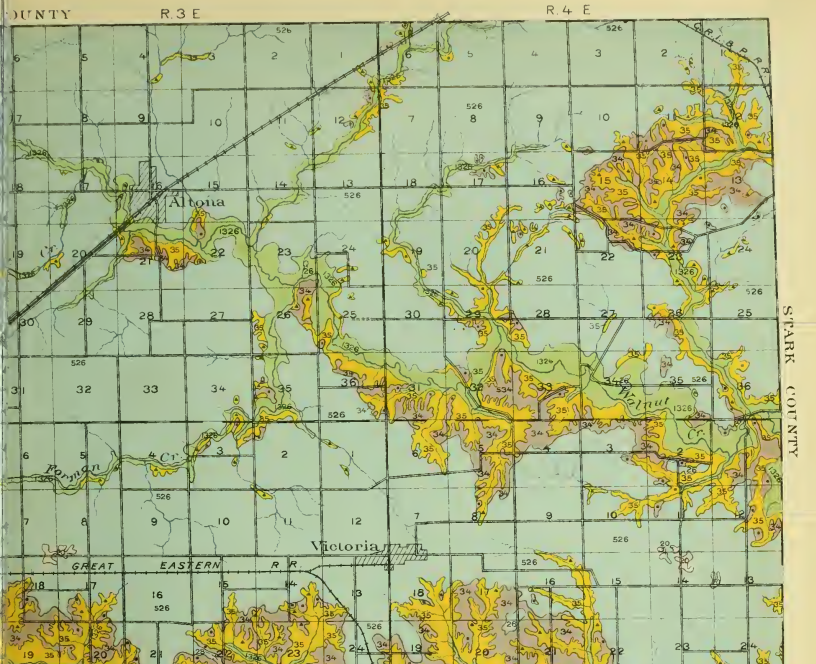


SWAMP AND BOTTOM LAND SOILS

silt loam

am

t loam on tight clay

1326 Deep brown silt loam

1301 Deep peat

1303 Shallow peat on clay

200 Illinois Moraines

Scale
0 ¼ ½ 1 2 Miles

OF KNOX COUNTY

ULTURAL EXPERIMENT STATION

because the large roots of dead trees and the surface accumulations of leaves, twigs, and fallen trees were burned by forest fires or suffered almost complete decay. The timber lands are divided chiefly into two classes—the undulating and the hilly areas.

(3) Swamp and bottom lands, which include the flood plains along streams and some small peaty swamp areas.

Table 1 gives the area of each type of soil in the county and its percentage of the total area. It will be observed that more than half the entire county is covered with the common prairie soil known as brown silt loam, and that about one-third consists of two upland timber types, the yellow silt loam (hilly) and the yellow-gray silt loam (undulating), the former occupying almost one-fifth of the entire county.

TABLE 1.—SOIL TYPES OF KNOX COUNTY

Soil type No. [1]	Name of type	Area in square miles	Area in acres	Percent of total area
	(a) Upland Prairie Soils (page 22)			
526	Brown silt loam	402.60	257 664	55.87
520	Black clay loam	8.31	5 318	1.15
528	Brown-gray silt loam on tight clay	.46	295	.06
	(b) Upland Timber Soils (page 26)			
534	Yellow-gray silt loam	104.43	66 836	14.48
535	Yellow silt loam	133.71	85 574	18.56
532	Light gray silt loam on tight clay	.02	12	.003
	(c) Swamp and Bottom-Land Soils (page 30)			
1326	Deep brown silt loam	71.09	45 498	9.86
1303	Shallow peat on clay	.03	19	.004
1301	Deep peat	.04	26	.006
	Total	720.69	461 242	100.00

[1]Soil types Nos. 226, 234, 235, and 232, as found on the maps, represent the same types as Nos. 526, 534, 535, and 532, except that the former are found on morainal areas.

The accompanying maps show the location and boundary lines of every type of soil in the county, even down to areas of a few acres; and in Table 2 are reported the amounts of organic carbon (the best measure of the organic matter) and the total amounts of the five important elements of plant food contained in 2 million pounds of the surface soil of each type (the plowed soil of an acre about 6⅔ inches deep). In addition, the table shows the amount of limestone present, if any, or the amount of limestone required to neutralize the acidity existing in the soil.[1]

[1]The figures given in Table 2 (and in the corresponding tables for subsurface and subsoil) are the averages for all determinations with some exceptions of limestone present or required. Some soil types, particularly those which are subject to erosion, may vary from acid to alkaline, especially in the subsurface or subsoil; and in such cases the word used in the table (see Table 11) is more useful than any average of figures involving both plus and minus quantities.

THE INVOICE AND INCREASE OF FERTILITY IN KNOX COUNTY SOILS

SOIL ANALYSIS

In order to avoid confusion in applying in a practical way the technical information contained in this report, the results are given in the most simplified form. The composition reported for a given soil type is, as a rule, the average of many analyses, which, like most things in nature, show more or less variation; but for all practical purposes the average is most trustworthy and sufficient. (See Bulletin 123, which reports the general soil survey of the state, together with many hundred individual analyses of soil samples representing twenty-five of the most important and most extensive soil types in the state.)

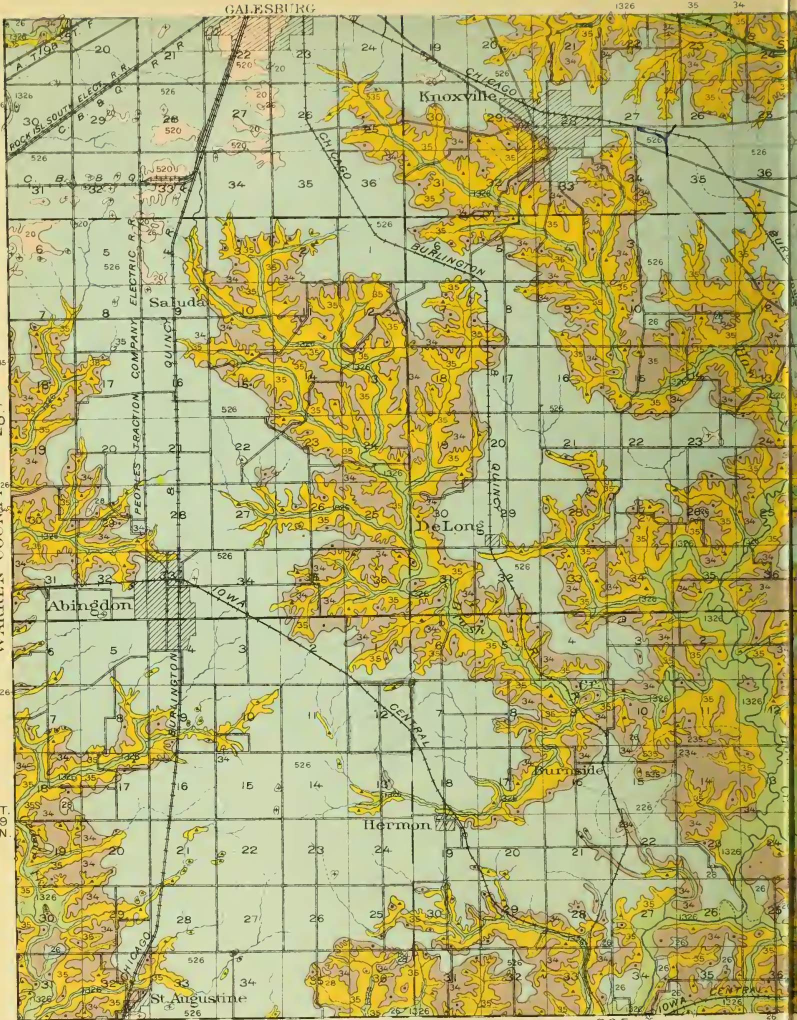
The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but, as explained in the Appendix, the rate of liberation is governed by many factors. Also, as there stated, probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that the productive power of normal soil in humid sections depends upon the stock of plant food contained in the soil and upon the rate at which it is liberated.

The fact may be repeated, too, that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all plants, only one (hydrogen) from water, while seven are secured from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes) in case the amount liberated from the soil is insufficient. But even the leguminous plants (which include the clovers, peas, beans, alfalfa, and vetches), in common with other agricultural plants, secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron, and sulfur) and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Table A in the Appendix shows the requirements of large crops for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally from natural sources in sufficient abundance compared with the amounts needed by plants, so that they are never known to limit the yield of common farm crops.)

As stated, the data in Table 2 represent the total amounts of plant-food elements found in 2 million pounds of surface soil,[1] which corresponds to an acre about 6⅔ inches deep. This includes at least as much soil as is ordinarily turned with the plow, and represents that part with which the farm manure, limestone, phosphate, or other fertilizer applied in soil improvement is incorporated. It is the soil stratum that must be depended upon

[1]The weight of peat is figured at ½ the weight of normal soils.



LEGEND

UPLAND PRAIRIE SOILS

26 / 526	Brown silt loam
20 / 520	Black clay loam
28 / 528	Brown-gray silt loam on tight clay

UPLAND TIMBER SO

34 / 534	Yello
36 / 536	Yello
32 / 532	Ligh

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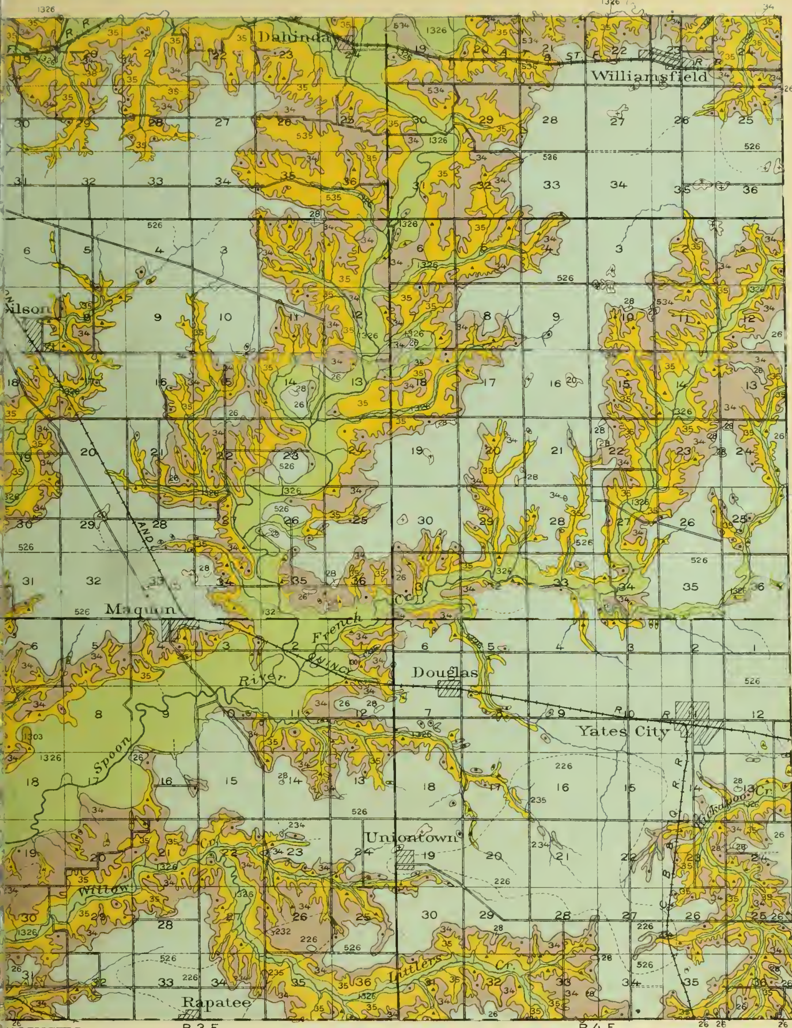


SWAMP AND BOTTOM LAND SOILS

ay silt loam

t loam

y silt loam on tight clay

1326 Deep brown silt loam

1301 Deep peat

1303 Shallow peat on clay

200 Illinois Moraines

Scale

0 ¼ ½ 1 2 Miles

OF KNOX COUNTY

ULTURAL EXPERIMENT STATION

TABLE 2.—FERTILITY IN THE SOILS OF KNOX COUNTY
Average pounds per acre in 2 million pounds of surface soil[1] (about 0 to 6⅔ inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone requir'd
	Upland Prairie Soils								
526	Brown silt loam	65 750	5 150	1 200	32 730	9 670	12 400		70
520	Black clay loam	92 450	7 650	1 840	29 710	13 830	23 880		40
528	Brown-gray silt loam on tight clay..........	43 960	3 320	1 000	33 900	7 900	9 560		80
	Upland Timber Soils								
534	Yellow-gray silt loam	25 900	2 440	860	33 930	6 620	8 300		120
535	Yellow silt loam	25 420	2 330	820	36 100	7 090	7 930		60
532	Light gray silt loam on tight clay..........	26 480	2 020	980	36 020	6 500	9 160		80
	Swamp and Bottom Land Soils								
1326	Deep brown silt loam	60 790	4 910	1 790	36 190	10 250	12 130		50
1301	Deep peat......	222 100	15 730	1 410	3 660	8 590	160 960	345 670	
1303	Shallow peat on clay..........	279 660	21 870	2 070	8 920	8 660	26 760	4 810	

[1]In 1 million pounds of peat (1301 and 1303).

in large part to furnish the necessary plant food for the production of crops, as will be seen from the information given in the Appendix. Even a rich subsoil has little or no value if it lies beneath a worn-out surface, but if the fertility of the surface soil is maintained at a high point, then the strong, vigorous plants will have power to secure more plant food from the subsurface and subsoil than would weak, shallow-rooted plants.

By easy computation it will be found that the most common prairie soil of Knox county does not contain more than enough total nitrogen in the plowed soil for the production of maximum crops for ten rotations (40 years); while the upland timber soils contain, as an average, less than one-half as much nitrogen as the prairie land.

With respect to phosphorus, the condition differs only in degree, nine-tenths of the soil area of the county containing no more of that element than would be required for sixteen crop rotations if such yields were secured as are suggested in Table A of the Appendix. It will be seen from the same table that in the case of the cereals about three-fourths of the phosphorus taken from the soil is deposited in the grain, while only one-fourth remains in the straw or stalks.

On the other hand, the potassium is sufficient for 25 centuries if only the grain is sold, or for 400 years even if the total crops should be removed and nothing returned. The corresponding figures are about 2500 and 600 years for magnesium, and about 15,000 and 300 years for calcium.

Thus, when measured by the actual crop requirements for plant food, potassium is no more limited than magnesium and calcium, and, as explained in the Appendix, with these elements we must also consider the fact that loss by leaching is far greater than by cropping.

These general statements relating to the total quantities of plant food in the plowed soil certainly emphasize the fact that the supplies of some of these necessary elements of fertility are extremely limited when measured by the needs of large crop yields for even one or two generations of people.

The variation among the different soil types with respect to their content of important plant-food elements is also very marked. Thus, the prairie soils contain two to three times as much nitrogen as the timber lands of the same topography; and the richest prairie land contains twice as much phosphorus as the common upland timber soils.

On the other hand, the most significant fact revealed by the investigation of the Knox county soils is the low phosphorus content of the common brown silt loam prairie, a type of soil which covers more than half the entire county. The market value of this land is about $200 an acre, and yet an application of forty dollars' worth of fine-ground raw rock phosphate

PLATE 1. WHEAT IN 1911 ON URBANA FIELD
COVER CROPS AND CROP RESIDUES PLOWED UNDER
AVERAGE YIELD, 35.2 BUSHELS PER ACRE

would double the phosphorus content of the plowed soil, and, if properly made, would in the near future double the yield of clover on the normal prairie soil and the undulating upland timber soils. If the clover was then returned to the soil, either directly or in farm manure, the combined effect of phosphorus and increased nitrogenous organic matter, with a good rotation of crops, would in time double the yield of corn on most farms.

With 5,000 pounds of nitrogen in the prairie soil and an inexhaustible supply in the air, with 33,000 pounds of potassium in the same soil and with practically no acidity, the economic loss in farming such land with only 1200 pounds of total phosphorus in the plowed soil can be appreciated only by the man who fully realizes that in less than one generation the crop yields could be doubled by adding phosphorus,—without change of seed or season and with very little more work than is now devoted to the fields.

Fortunately, some definite field experiments have already been conducted

PLATE 2. WHEAT IN 1911 ON URBANA FIELD
COVER CROPS AND CROP RESIDUES PLOWED UNDER
FINE-GROUND ROCK PHOSPHATE APPLIED
AVERAGE YIELD, 50.1 BUSHELS PER ACRE

on this most extensive type of soil, both in Knox county and on similar soil in several other counties, as at Urbana in Champaign county, at Sibley in Ford county, and at Bloomington in McLean county.

Results of Field Experiments at Urbana

A three-year rotation of corn, oats, and clover was begun on the North Farm at the University of Illinois in 1902, on three fields of typical brown silt loam prairie land which, after twenty years or more of pasturing, had grown corn in 1895, 1896, and 1897 (when careful records were kept of the yields produced) and had then been cropped with clover and grass on one field, oats on another, and oats, cowpeas, and corn on the third field, until 1901.

As an average of the first three years (1902-1904) phosphorus increased

Plate 3. Wheat in 1911 on Urbana Field
Cover Crops and Farm Manure Plowed Under
Average Yield, 34.2 Bushels Per Acre

TABLE 3.—EFFECT OF PHOSPHORUS ON BROWN SILT LOAM AT URBANA
(Average increase per acre)

Rotation	Years	Corn, bu.	Oats, bu.	Clover, tons	Value of increase[1]	Cost of treatment[1]
First..........	1902,-3,-4	8.8	1.9	.68	$ 7.73	$7.50
Second	1905,-6,-7	13.2	11.9	.79	12.93	7.50
Third.........	1908,-9,-10	18.7	8.4	1.05	15.37	7.17

[1]Prices used are 35 cents a bushel for corn, 30 cents for oats, $6 a ton for clover hay, 10 and 3 cents a pound, respectively, for phosphorus in bone meal and in rock phosphate.

the crop yields per acre by .68 ton of clover, 8.8 bushels of corn, and 1.9 bushels of oats. During the second three years (1905-1907) it produced average increases of .79 ton of clover, 13.2 bushels of corn, and 11.9 bushels of oats. During the third course of the rotation (1908-1910) it produced aver-

PLATE 4. WHEAT IN 1911 ON URBANA FIELD
COVER CROPS AND FARM MANURE PLOWED UNDER
FINE-GROUND ROCK PHOSPHATE APPLIED
AVERAGE YIELD, 51.8 BUSHELS PER ACRE

age increases of 1.05 tons of clover, 18.7 bushels of corn, and 8.4 bushels of oats. For convenient reference the results are summarized in Table 3.

Wheat is grown on the University South Farm in a rotation experiment started more recently. As an average of the four years 1908 to 1911, raw rock phosphate (with no previous application of bone meal) increased the yield of wheat by 10.3 bushels per acre. Here too, as an average of the four years, the phosphorus applied paid back about twice its cost.

In the grain system of farming, the yield of wheat in 1911 was 35.2 bushels per acre where cover crops and crop residues are plowed under without the use of phosphorus; but where rock phosphate is used the average yield was 50.1 bushels. (See Plates 1 and 2.)

In the live-stock system, the yield of wheat in 1911 was 34.2 bushels where manure and cover crops are used without phosphate, and 51.8 bushels, as an average, where rock phosphate is used in addition. (See Plates 3 and 4.)

These results emphasize the cumulative effect of permanent systems of soil improvement.

Wheat has also been grown on the North Farm during the last three years, and the average increase produced by phosphorus (part in bone meal and part in raw phosphate) has been 12.4 bushels per acre.

RESULTS OF EXPERIMENTS ON SIBLEY FIELD

Table 4 gives the results obtained during the past eleven years from the Sibley soil experiment field located in Ford county on the typical brown silt loam prairie of the Illinois corn belt.

Previous to 1902 this land had been cropped with corn and oats for many years under a system of tenant farming, and the soil had become somewhat deficient in active organic matter. While phosphorus was the limiting element of plant food, the supply of nitrogen becoming available annually was but little in excess of the phosphorus, as is well shown by the corn yields for 1903, when phosphorus produced an increase of 8 bushels, nitrogen without phosphorus produced no increase, but nitrogen and phosphorus together increased the yield by 15 bushels.

After six years of additional cropping, however, nitrogen appears to have become the most limiting element, the increase in the corn in 1907 having been 9 bushels from nitrogen and only 5 bushels from phosphorus, while both together produced an increase of 33 bushels. By comparing the corn yields for the four years 1902, 1903, 1906, and 1907, it will be seen that the untreated land has apparently grown less productive, whereas on land receiving both phosphorus and nitrogen the yield has appreciably increased, so that in 1907, when the untreated rotated land produced only 34 bushels of corn per acre, a yield of 72 bushels (more than twice as much) was produced where lime, nitrogen, and phosphorus had been applied, altho the two plots produced exactly the same yield (57.3 bushels) in 1902.

Even in the unfavorable season of 1910, the yield of the highest-producing plot exceeded that of 1902, while the untreated land produced less than half as much as it produced in 1902. The prolonged drouth of 1911 resulted in almost a failure of the corn crop, but nevertheless the effect of soil treatment is seen. Phosphorus appears to have been the first limiting element again in 1909, 1910, and 1911; while the lodging of oats, especially on the

TABLE 4.—CROP YIELDS IN SOIL EXPERIMENTS, SIBLEY FIELD

Brown silt loam prairie; early Wisconsin glacation		Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912
Plot	Soil treatment applied	Bushels per acre										
101	None	57.3	50.4	74.4	29.5	36.7	33.9	25.9	25.3	26.6	20.7	84.4
102	Lime	60.0	54.0	74.7	31.7	39.2	38.9	24.7	28.8	34.0	22.2	85.6
103	Lime, nitrogen	60.0	54.3	77.5	32.8	41.7	48.1	36.3	19.0	29.0	22.4	25.3
104	Lime, phosphorus	61.3	62.3	92.5	36.3	44.8	43.5	25.6	32.2	52.0	31.6	92.3
105	Lime, potassium	55.0	49.9	74.4	30.2	37.5	34.9	22.2	23.2	34.2	21.6	83.1
106	Lime, nitrogen, phosphorus	57.3	69.1	88.4	45.2	68.5	72.3	45.6	33.3	55.6	35.3	42.2
107	Lime, nitrogen, potassium	53.3	51.4	75.9	37.7	39.7	51.1	42.2	25.8	46.2	20.1	55.6
108	Lime, phosphorus, potassium	58.7	60.9	80.0	39.8	41.5	39.8	27.2	28.5	43.0	31.8	79.7
109	Lime, nitrogen, phos., potas.	58.7	65.9	82.5	48.0	69.5	80.1	52.8	35.0	58.0	35.7	57.2
110	Nitro., phos., potassium	60.0	60.1	85.0	48.5	63.3	72.3	44.1	30.8	64.4	31.5	54.1
	Average Increase: Bushels per Acre											
	For nitrogen	−1.7	3.4	.7	6.4	14.1	23.6	19.3	.1	6.4	1.6	−40.1
	For phosphorus	1.7	12.1	10.7	9.2	16.5	15.7	6.4	8.1	16.3	12.0	5.4
	For potassium	−3.0	−2.9	−5.1	2.4	−1.5	1.0	3.0	− .2	2.7	− .6	7.5
	For nitro., phos., over phos.	−4.0	6.8	−4.1	8.9	23.7	28.8	20.0	1.1	3.6	3.7	−50.1
	For phos., nitro. over nitro.	−2.7	14.8	10.9	12.4	26.8	24.2	9.3	14.3	26.6	12.9	16.9
	For potas., nitro., phos. over nitro., phos.	1.4	−3.2	−5.9	2.8	1.0	7.8	7.2	1.7	2.4	.4	15.0

Value of Crops per Acre in Eleven Years

Plot	Soil treatment applied	Total value of eleven crops	Value of increase
101	None	$ 172.73	
102	Lime	184.75	$ 12.02
103	Lime, nitrogen	167.42	— 5.31
104	Lime, phosphorus	214.50	41.77
105	Lime, potassium	173.22	.49
106	Lime, nitrogen, phosphorus	233.15	60.42
107	Lime, nitrogen, potassium	188.19	15.46
108	Lime, phosphorus, potassium	200.37	27.64
109	Lime, nitrogen, phosphorus, potassium	244.62	71.89
110	Nitrogen, phosphorus, potassium	233.54	60.81

Value of Increase per Acre in Eleven Years		Cost of increase
For nitrogen	$-17.33	$ 165.00
For phosphorus	29.75	27.50
For *nitrogen* and phosphorus over phosphorus	18.65	165.00
For *phosphorus* and nitrogen over nitrogen	65.73	27.50
For *potassium*, nitrogen, and phosphorus over nitrogen and phosphorus	11.47	27.50

nitrogen plots, in the exceptionally favorable season of 1912, produced very irregular results.

In the lower part of Table 4 are shown the total values per acre of the eleven crops from each of the ten different plots, the amounts varying from $167.42 to $244.62; also the value of the increase produced in crop yields above the value of the yields from the untreated land, corn being valued at 35 cents a bushel, oats at 30 cents, and wheat at 70 cents. Phosphorus without nitrogen produced $29.75 in addition to the increase by lime; but, with nitrogen, it produced $65.73 above the crop values where only lime and nitrogen were used. The results show that in 25 cases out of 44 the addition of potassium decreased the crop yields. Even under the most favorable conditions, and with no effort to liberate potassium from the soil by adding organic matter, potassium paid back less than half its cost.

By comparing Plots 101 and 102, and also 109 and 110, it will be seen that the average increase produced by lime was $11.55, or more than $1 an acre a year. Altho this increase may have been above normal on these plots because of the "condition" of the soil at the beginning, it suggests that the time is here when limestone must be applied to some of these brown silt loam soils. While nitrogen produced an appreciable increase, especially when phosphorus was provided, the only conclusion to be drawn, if we are to utilize this fact to advantage, is that the nitrogen must be secured from the air.

RESULTS OF EXPERIMENTS ON BLOOMINGTON FIELD

Space is taken to insert Table 5, giving all of the results thus far obtained from the Bloomington soil experiment field, which is also located on the brown silt loam prairie soil of the Illinois corn belt.

The general results of the eleven years' work on the Bloomington field tell much the same story as those from the Sibley field. The rotations differed by the use of clover and by discontinuing the use of commercial nitrogen on the Bloomington field after 1905, in consequence of which phosphorus without commercial nitrogen (Plot 104) produced an even larger increase ($89.92) than was produced by phosphorus over nitrogen ($65.73) on the Sibley field (see Plots 103 and 106).

It should be stated that a draw runs near Plot 110 on the Bloomington field, that the crops on that plot are sometimes damaged by overflow or imperfect drainage, and that Plot 101 occupies the lowest ground on the opposite side of the field. In part because of these irregularities and in part because only one small application has been made, no conclusions can be drawn in regard to lime. Otherwise all results reported in Table 5 are considered reliable. They not only furnish much information in themselves but they also offer instructive comparisons with the Sibley field.

Wherever nitrogen was provided, either by direct application or by the use of legume crops, the addition of the element phosphorus produced very marked increases, the average yearly increase for the Bloomington field being worth $7.11 an acre. This is $4.61 above the cost of the phosphorus in 200 pounds of steamed bone meal, the form in which it was applied to the Sibley and Bloomington fields. On the other hand, the use of phosphorus without nitrogen will not maintain the fertility of the soil (see Plots 104 and 106, Sibley field). As the only practical and profitable method of supplying the nitrogen, a liberal use of clover or other legumes is suggested, the legume to be plowed

TABLE 5.—CROP YIELDS IN SOIL EXPERIMENTS, BLOOMINGTON FIELD

Plot	Brown silt loam prairie; early Wisconsin glaciation — Soil treatment applied	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Corn 1908	Oats 1909	Clover[2] 1910	Wheat 1911	Corn 1912
		Bushels or tons per acre										
101	None	30.8	63.9	54.8	30 8	.39	60.8	40.3	46.4	1.56	22.5	55.2
102	Lime	37.0	60.3	60.8	28.8	.58	63.1	35.3	53.6	1.09	22.5	47.9
103	Lime, crop res.[1]	35.1	59.5	69.8	30.5	.46	64.3	36.9	49.4	(.83)	25.6	62.5
104	Lime, phosphorus	41.7	73.0	72.7	39.2	1.65	82.1	47.5	63.8	4.21	57.6	74.5
105	Lime, potassium	37.7	56.4	62.5	33.2	.51	64.1	36.2	45.3	1.26	21.7	57.8
106	Lime, residues,[1] phosphorus	43.9	77.6	85.3	50.9	[3]	78.9	45.8	72.5	(1.67)	60.2	86.1
107	Lime, residues,[1] potassium	40.4	58.9	66.4	29.5	.81	64.3	31.0	51.1	(.33)	27.3	58.9
108	Lime, phosphorus, potassium	50.1	74.8	70.3	37.8	2.36	81.4	57.2	59.5	3.27	54.0	79.2
109	Lime, res.,[1] phos., potassium	52.7	80.9	90.5	51.9	[3]	88.4	58.1	64.2	(.42)	60.4	83.4
110	Res., phosphorus, potassium	52.3	73.1	71.4	51.1	[3]	78.0	51.4	55.3	(.60)	61.0	78.3

Average Increase: Bushels or Tons per Acre

	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Corn 1908	Oats 1909	Clover 1910	Wheat 1911	Corn 1912
For residues	1.4	3.1	11.4	5.9	−.96	1.3	−1.1	3.7	−1.64	4.4	7.9
For phosphorus	9.5	17.8	14.8	14.4	.41	18.8	18.0	15.1	1.51	33.9	24.0
For potassium	5.8	.2	.3	.7	.25	2.4	4.2	−4.8	−.63	−.6	2.1
For res.,phos. over phos.	2.2	4.6	12.6	11.7	−.65	−3.2	−1.7	8.7	−2.25	2.6	11.6
For phos.,res. over res.	8.8	18.1	15.5	20.4	−1.46	14.6	8.9	23.1	.84	34.6	23.6
For potas., res., phos. over res., phos.	8.8	3.3	5.2	1.0	.00	9.5	12.3	−8.3	−1.25	.2	−2.7

Value of Crops per Acre in Eleven Years

Plot	Soil treatment applied	Total value of eleven crops	Value of increase
101	None	$167.22	
102	Lime	165.52	−$1.70
103	Lime, residues	173.17	5.95
104	Lime, phosphorus	255.44	88.22
105	Lime, potassium	169.66	2.44
106	Lime, residues, phosphorus	251.43	84.21
107	Lime, residues, potassium	170.57	3.35
108	Lime, phosphorus, potassium	256.92	89.70
109	Lime, residues, phosphorus, potassium	254.76	87.54
110	Residues, phosphorus, potassium	236.66	69.44

Value of Increase per Acre in Eleven Years		Cost of increase
For residues	$ 7.65	?
For phosphorus	89.92	$27.50
For *residues* and phosphorus over phosphorus	−4.01	?
For *phosphorus* and residues over residues	78.26	27.50
For *potassium*, residues, and phosphorus over residues and phosphorus	3.33	27.50

[1]Commercial nitrogen was used 1902–1905.
[2]The figures in parentheses mean bushels of seed; the others, tons of hay.
[3]Clover smothered by previous wheat crop.

under either directly or as manure, preferably in connection with the phosphorus applied, especially if raw rock phosphate is used.

From the soil of the best treated plots, 160 pounds per acre of phosphorus, as an average, were removed in the eleven crops. This is equal to more than 13 percent of the total phosphorus contained in the surface soil of an acre of the untreated land. In other words, if such crops could be grown for eighty years, they would require as much phosphorus as the total supply in the ordinary plowed soil. The results plainly show, however, that without the addition of phosphorus such crops cannot be grown year after year. Where no phosphorus was applied, the crops removed only 107 pounds of phosphorus in the eleven years, which is equivalent to only 9 percent of the total amount (1,200 pounds) in the surface soil at the beginning (1902). The total phosphorus applied from 1902 to 1912, as an average of all plots where it was used, amounted to 275 pounds per acre and cost $27.50. This paid back $84.91, or 300 percent on the investment; whereas potassium, used in the same number of tests and at the same cost, paid back only $1.59 per acre in the eleven years, or less than 6 percent of its cost. Are not these results to be expected from the composition of the soil and the requirements of crops? (See Table 2, page 7, and also Table A in the Appendix.)

Nitrogen was applied to this field in commercial form only, from 1902 to 1905; but clover was grown in 1906 and 1910, and a catch crop of cowpeas after the clover in 1906. The cowpeas were plowed under on all plots, and the 1910 clover (except the seed) was plowed under on five plots (103, 106, 107, 109, and 110). Straw and corn stalks have also been returned to these plots in recent years. The effect of returning these residues to the soil is already appreciable (an average increase of 4.4 bushels of wheat in 1911 and 7.9 bushels of corn in 1912) and probably will be more marked on subsequent crops. Indeed, the large crops of corn, oats, and wheat grown on Plots 104 and 108 during the eleven years drew their nitrogen very largely from the natural supply in the organic matter of the soil.

The roots and stubble of clover contain no more nitrogen than the entire plant takes from the soil alone, but they decay rapidly in contact with the soil and probably hasten the decomposition of the soil humus and the consequent liberation of the soil nitrogen. But of course there is a limit to the reserve stock of humus and nitrogen remaining in the soil, and the future years will undoubtedly witness a gradually increasing difference between Plots 104 and 106 and between Plots 108 and 109, in the yields of grain crops.

In Plate 5 are shown graphically the relative values of the eleven crops for the eight comparable plots, Nos. 102 to 109. The cost of the phosphorus is indicated by that part of the diagram above the short crossbars. It should be kept in mind that no value is assigned to clover plowed under except as it reappears in the increase of subsequent crops. Plots 106 and 109 are heavily handicapped because of the clover failure on those plots in 1906 and the poor yield of clover seed in 1910, whereas Plots 104 and 108 produced a fair crop in 1906 and a very large crop in 1910. As an average, Plots 106 and 109 are only $3.09 behind Plots 104 and 108 in the value of the eleven crops harvested, and this would have been covered by about ½ bushel more clover seed in 1906 or 1910, or it may be covered by 10 bushels more corn in 1913. The values from Plots 103 and 107 average $4.28 more than the values from Plots 102 and 105. (See also table on last page of cover.)

(R stands for residues; P, for phosphorus, and K, for potassium Kalium.)

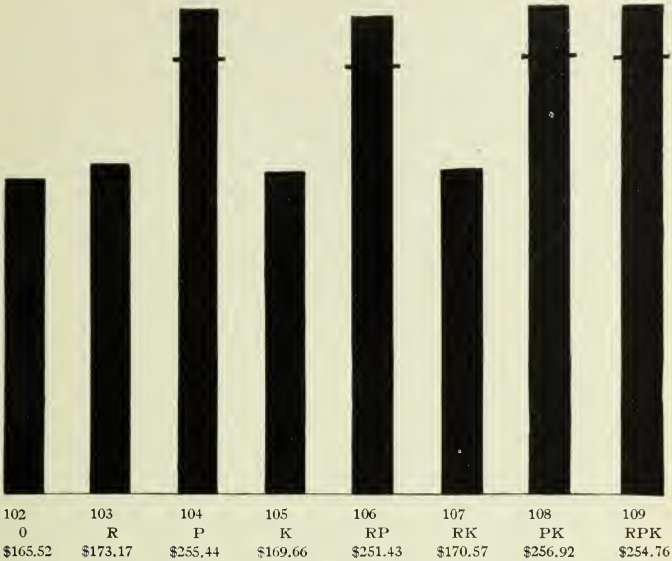


PLATE 5. CROP VALUES FOR ELEVEN YEARS, BLOOMINGTON EXPERIMENT FIELD

RESULTS OF FIELD EXPERIMENTS AT GALESBURG

In Tables 6, 7, and 8 are reported in detail the results obtained from the University of Illinois soil experiment field near Galesburg, on the line between Knox and Warren counties, on the brown silt loam prairie soil of the upper Illinois glaciation.

A six-year rotation has been practiced on this field since 1904. During the first six years the order of cropping was corn, corn, oats, wheat, followed by two years of clover and timothy. Since then the rotation has been corn, corn, oats, clover, wheat, clover. There are only three independent series of plots, so that while corn is grown every year the other crops are harvested only in alternate years, altho clover should be on the field every year, either in the stubble of the oats and wheat or as a regular crop.

Each series contains twenty individual fifth-acre plots 2 rods wide and 16 rods long, with half-rod division strips cultivated and cropped between the plots, a quarter-rod border cultivated and cropped surrounding each series, and grass strips about two rods wide between the series and surrounding the experiment field. The soil treatment for the individual plots is indicated in Tables 6, 7, and 8.

Limestone was applied in small amount (1300 pounds per acre) to the first fifteen plots in each series in 1904. No further application was made until the spring of 1912, when 4 tons per acre was applied to Plots 1 to 15 of Series

TABLE 6.—CROP YIELDS IN SOIL EXPERIMENTS, GALESBURG FIELD: SERIES 100

Brown silt loam prairie; upper Illinois glaciation		Corn 1904	Corn 1905	Oats 1906	Wheat 1907	Clover[1] 1908	Timothy[1] 1909	Corn 1910	Corn 1911	Oats 1912
Plot	Soil treatment applied	Bushels or tons per acre								
101	Lime	63.8	52.5	53.8	34.0	2.71	2.04	59.8	66.5	53.3
102	Residues, lime	67.3	49.8	53.6	41.4	(.96)	(3.83)	72.6	75.1	56.9
103	Manure, lime	64.7	48.1	50.3	31.6	2.59	1.83	77.6	81.0	60.0
104	Cover crop, manure, lime...	65.3	46.5	46.7	32.8	2.61	1.70	77.9	78.9	70.2
105	Lime....	74.7	54.9	52.3	35.1	2.80	2.05	66.2	67.4	60.8
106	Lime, phosphorus..........	78.2	66.1	53.9	41.9	3.18	2.58	72.4	79.4	68.6
107	Residues, lime, phosphorus	75.9	63.1	55.0	41.3	(.67)	(4.92)	78.0	83.8	65.2
108	Manure, lime, phosphorus..	72.6	61.1	54.2	37.9	3.18	2.36	74.6	79.8	77.3
109	Cover crop, manure, lime, phosphorus............	74.1	60.0	54.2	40.0	3.15	2.33	74.0	79.1	74.4
110	Lime......................	72.4	58.8	50.5	32.7	2.65	1.74	61.5	59.2	54.5
111	Lime, phosphorus, potassium	81.2	72.3	53.9	36.6	3.21	2.42	74.5	81.1	70.9
112	Residues, lime, phosphorus, potassium...............	82.3	71.0	59.4	41.1	(.58)	(5.00)	81.9	83.7	59.5
113	Manure, lime, phosphorus, potassium	77.1	72.2	52.8	36.1	3.45	2.49	77.6	82.4	74.4
114	Cover crop, manure, lime, phos., potassium........	89.4	69.9	54.5	38.7	3.36	2.55	75.9	85.0	70.0
115	Lime.................. ...	81.2	68.1	62.8	36.8	2.99	2.19	59.4	67.3	53.0
116	Residues...	77.1	61.8	57.3	38.2	(1.17)	(5.33)	70.6	68.9	52.0
117	Residues, phosphorus......	79.4	64.2	60.0	36.2	(1.25)	(5.50)	75.0	77.5	66.1
118	Residues, phosphorus, potassium...............	82.3	70.8	52.0	40.9	(1.38)	(4.75)	78.3	78.4	68.1
119	Residues, lime, nitrogen, phos., potassium........	87.1	76.3	66.2	46.0	(1.08)	(5.00)	74.8	79.3	67.3
120	None.......................	82.9	65.1	65.3	45.8	3.04	2.82	72.7	67.4	70.2
Increase for residues.						—2.19	—.89	5.9	4.3	—7.3
Increase for manure............								7.7	5.4	6.3
Increase for phosphorus........		6.2	10.7	3.4	3.6	.26	.42	1.8	5.7	10.3
Increase for potassium........		6.4	8.3	—.9	—.8	.11	—.01	2.8	2.2	—1.7
Increase for nitrogen		4.8	5.5	14.2	5.1	—(.30)	(.25)	—3.5	.9	—.8

[1]The figures in parentheses in these columns represent bushels of seed; the others, tons of hay.

300. Thus far no apparent effect has been produced, but further experiment with liberal applications may show results. Plots 1 to 15 in Series 100 and 200 were given 4 tons per acre in the spring of 1913.

The "residues" include the straw and corn stalks, all clover except the seed, and legume cover crops, such as cowpeas, soybeans, or vetch, seeded in the corn at the last cultivation. They are returned to certain plots to supply nitrogen and organic matter in a system of grain farming. This system was not fully under way on all series until 1911, as may be seen from the lower parts of Tables 6, 7, and 8, so that as yet no conclusions regarding this treatment are justified, except that an abundance of organic matter is thus provided. Whether the value of the clover plowed under will ultimately reappear in subsequent yields of grain and seed, must be determined by the further accumulation of data.[1]

[1]Alsike clover promises to yield the better returns in seed, altho in some cases seed has been threshed from both the first and second cuttings of the red clover. It is quite possible that better average results would be secured by regularly removing the first cutting of red clover, with the purpose of threshing it for seed, as well as the second cutting if found

TABLE 7.—CROP YIELDS IN SOIL EXPERIMENTS, GALESBURG FIELD: SERIES 200

Brown silt loam prairie; upper Illinois glaciation		Oats 1904	Wheat 1905	Clover 1906	Timothy 1907	Corn 1908	Corn 1909	Oats 1910	Clover 1911	Wheat 1912
Plot	Soil treatment applied	Bushels or tons per acre								
201	Lime	57.5	40.5	.72	2.30	79.8	54.1	48.0	1.39	17.5
202	Residues, lime	55.0	40.0	.63	1.31	78.8	51.9	43.3		21.1
203	Manure, lime	52.5	38.5	.57	2.55	101.3	65.6	50.6	2.64	21.7
204	Cover crop, manure, lime	55.0	40.2	.63	2.73	102.7	66.8	53.0	2.32	19.6
205	Lime	67.5	42.2	1.22	2.84	86.3	54.4	44.4	2.29	18.2
206	Lime, phosphorus	62.5	41.3	1.36	3.27	99.6	59.1	55.5	2.42	27.3
207	Residues, lime, phosphorus	57.5	42.2	.90	1.79	105.6	49.4	48.6		27.3
208	Manure, lime, phosphorus	60.0	40.0	.91	3.18	106.6	69.8	58.6	2.30	27.3
209	Cover crop, manure, lime, phos.	50.0	39 0	.91	3.16	105.8	75.7	60.3	2.03	27.8
210	Lime	57.5	37.5	.69	2.46	84.5	57.8	42.3	1.14	12.2
211	Lime, phosphorus, potassium	55.0	38.7	1.31	3.38	95.7	67.0	55.3	2.01	28.2
212	Residues, lime, phosphorus, potassium	65.0	39.3	1.40	2.15	103.3	57.5	53.8		28.3
213	Manure, lime, phosphorus, potassium	65.0	41.5	1.79	3.62	98.1	69.8	58.3	2.55	25.9
214	Cover crop, manure, lime, phos., potas.	62.5	40.7	1.51	3.48	102.8	73.3	62.8	2.46	25.3
215	Lime	60.0	35.5	.83	2.33	84.1	58.2	41.6	.98	8.8
216	Residues	72.5	37.0	.82	1.37	87.3	54.8	38.6		11.8
217	Residues, phosphorus	57.5	38.7	.85	1.44	98.6	49.6	43.4		22.1
218	Residues, phosphorus, potassium	50.0	40.7	1.51	2.17	99.0	43.0	46.3		28.3
219	Residues, lime, nitrogen, phos., potas.	57.5	37.7	1.21	1.98	109.6	47.2	57.2		27.3
220	None	55.0	39.5	.71	2.49	88.3	49.5	38.1	1.00	15.6
Increase for residues								—3.1	—1.70	0.0
Increase for manure						7.7	8.3	2.9	.56	.6
Increase for phosphorus		—3.0	.7	.21	.41	12.0	2.0	7.3	—.17	7.7
Increase for potassium		2.0	— .1	.52	.39	—3.5	1.4	2.0	.09	.8
Increase for nitrogen		7.5	—3.0	—.30	—.19	10.6	4.2	10.9		—1.0

Farm manure is applied to certain plots (see tables) in proportion to their previous average crop yields, that is, as many tons of manure are applied to each plot as there were tons of average air-dry produce removed from the corresponding plots during the previous rotation; but no manure was used until crops had been grown for four years and the data had been thus accumulated from which to compute the proper applications of manure. The live-stock system was not fully under way on all series until 1912 (see lower parts of tables), when the average increase from the manure varied from ½ bushel of wheat to nearly 17 bushels of corn.

On Plots 4, 9, and 14 cover crops are grown as indicated in the tables, but the results thus far secured do not justify advising this practice, as may be seen by comparing these plots with Plots 3, 8, and 13, respectively.

advisable. Some splendid seed crops have been secured from the second cutting when the first was clipped and left on the land, but under other seasonal conditions the second crop has been a failure. In such cases, altho the apparent effect is a total loss of the clover crop, at least part of this apparent loss is recovered in subsequent crops of grain. It should never be forgotten that the purpose of this system is to enable the grain farmer to maintain the fertility of his soil, even tho some other system which he may not be prepard to adopt might be more profitable.

TABLE 8.—CROP YIELDS IN SOIL EXPERIMENTS, GALESBURG FIELD: SERIES 300

Brown silt loam prairie; upper Illinois glaciation		Timothy 1904	Timothy 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Wheat 1910	Clover 1911	Corn 1912
Plot	Soil treatment applied	Bushels or tons per acre								
301	Lime	1.36	1.54	66.8	75.9	28.6	31.7	16.2	2.17	70.8
302	Residues, lime	1.38	1.59	68.6	77.7	26.6	33.8	19.4		89.6
303	Manure, lime	1.30	1.92	72.0	80.3	28.3	36.3	19.6	2.57	104.3
304	Cover crop, manure, lime	1.38	2.02	75.6	83.1	26.1	40.4	22.3	2.03	103.3
305	Lime	1.20	1.75	70.5	78.3	22.5	36.6	21.2	1.83	92.1
306	Lime, phosphorus	1.21	1.65	69.7	84.4	32.7	40.6	22.2	2.64	98.2
307	Res., lime, phosphorus	1.16	1.55	74.0	84.1	27.5	41.2	24.1		103.2
308	Manure, lime, phosphorus	1.25	1.63	73.9	86.1	33.9	39.7	21.6	3.25	107.9
309	Cover crop, manure, lime, phosphorus	1.55	2.03	83.9	87.8	28.9	44.9	24.9	3.13	106.0
310	Lime	1.75	2.25	84.3	85.6	31.6	39.8	22.4	2.74	93.0
311	Lime, phosphorus, potassium	2.10	2.41	86.9	87.8	32.3	44.3	24.5	3.59	101.9
312	Residues, lime, phosphorus, potassium	1.55	1.91	75.8	81.2	25.9	41.8	23.2		98.4
313	Manure, lime, phosphorus, potassium	1.16	1.53	68.4	77.9	31.3	35.8	23.0	3.28	108.8
314	Cover crop, manure, lime, phos., potas.	1.50	1.52	70.6	81.7	27.7	42.0	23.1	3.57	106.9
315	Lime	1.90	1.97	74.1	85.1	30.6	36.8	21.6	2.47	90.6
316	Residues	1.82	1.82	67.7	80.6	26.7	34.2	22 9		82.1
317	Residues, phosphorus	1.95	2.00	59.1	83.3	31.1	44.9	27.0		99.2
318	Residues, phosphorus, potassium	2.65	2.18	66.8	73.6	25.8	43.3	29.1		113.2
319	Residues, lime, nitrogen, phos., potas.	4.15	2.37	71.2	84.7	32.7	43.8	24.9		104.1
320	None	1.46	1.56	59.6	72.8	31.3	28.5	15.8	1.46	79.1
Increase for residues									—2.46	5.8
Increase for manure										16.7
Increase for phosphorus		.01	—.05	1.2	5.1	4.8	6.0	2.9	.86	8.6
Increase for potassium		.37	.14	1.6	—4.7	—2.2	—.8	.6	.47	2.9
Increase for nitrogen		1.50	.19	4.4	11.1	6.9	.5	—4.2		—9.1

At the beginning of this experiment this field was all in timothy sod. Series 300 was not broken during the first two years, but ½ ton of raw rock phosphate per acre was applied as top-dressings. This produced practically no effect,—a result to be expected. A ton of phosphate per acre applied to Series 200 produced no effect on the oats seeded on timothy sod in 1904 and but little effect on the wheat which followed in 1905. Beginning with Series 100 in 1904, Series 300 in 1906, and Series 200 in 1908, the regular plan has been to apply 1½ tons of raw rock phosphate (375 pounds of phosphorus) per acre every six years before plowing for corn, in addition to the partial applications made as stated above. This plan has been followed essentially, and will be continued until the phosphorus content of the plowed soil is at least doubled, but ultimately the amounts applied for each rotation will be reduced to supply only about as much as is removed in the crops grown, and of course the annual expense for this element will then decrease accordingly.

Potassium is applied in the form of potassium sulfate, 100 pounds per acre of the sulfate (containing 42 pounds of potassium) being used for each year in the rotation. The application is made only in connection with the

phosphate in order to ascertain whether its use in this way is profitable, there being no doubt that it would be unprofitable if used alone.

In order to help settle the question whether commercial nitrogen could be used with profit, Plot 19 has received nitrogen at the rate of 25 pounds per acre per annum. Nearly the total amount for the first four years was applied in 1904, but since 1907 the applications have been made annually. The nitrogen has been applied in addition to crop residues, phosphorus, and potassium, but without limestone.

TABLE 9.—GALESBURG EXPERIMENT FIELD: FINANCIAL STATEMENT
(Value of increase from three acres)

Series 100.....	Corn	Corn	Oats	Wheat	Clover	Grass	Corn	Corn	Oats	Average 1907 to 1912
Series 200.....	Oats	Wheat	Clover	Grass	Corn	Corn	Oats	Clover	Wheat	
Series 300.....	Grass	Grass	Corn	Corn	Oats	Wheat	Wheat	Clover	Corn	
Years..........	1904	1905	1906	1907	1908	1909	1910	1911	1912	
For residues..					$13.14[1]	$-5.34[1]	$ 1.13[2]	$23.46	$ -.16	
For manure...					2.70[1]	2.90[1]	3.57[2]	5.25[2]	8.16	
For phosph'r's	$ 1.33	$ 3.93	$2.70	$6.77	7.20	7.42	4.85	6.14	11.49	$7.31
For potassium	5.06	3.67	3.41	.14	-1.22	-.13	2.00	4.13	1.06	1.00
For nitrogen..	12.93	.97	4.00	6.31	3.98	3.32	-.90	.31	-4.12	1.48

[1]One crop only.
[2]Two crops only.

In Table 9 is given a financial summary of the results thus far secured from the Galesburg field. Three facts are clearly brought out by the data:

First.—Commercial nitrogen at 15 cents a pound has never paid its cost, and as the system of providing "home-grown" nitrogen in crop residues has developed, the effect of commercial nitrogen has decreased, so that as an average of the last five years it has paid back only 4 percent of its annual cost.

Second.—Potassium, likewise, has never paid its cost, but during the early years, when no adequate provision was made for decaying organic matter, the soluble potassium salt produced a very marked effect, due in part no doubt to the fact that it helped to dissolve and make available the raw phosphate always applied with it. With the subsequent increase in decaying organic matter, the effect of potassium was greatly reduced. As an average of the last six years, potassium costing $7.50 has paid back only $1.

Third.—Phosphorus applied in fine-ground natural rock phosphate in part as top-dressing, and with no adequate provision for decaying organic matter, paid only 47 percent on the investment as an average of the first three years. But it should be kept in mind that the word *investment* is here used in its proper sense, for the phosphorus removed in the increase produced was less than 2 percent of the amount applied, and that removed in the total crops, less than one-third. During the last six years, however, the phosphorus has paid 130 percent on the investment, even tho two-thirds of the application remains to positively enrich the soil.

The results from the Galesburg experiment field furnish some interesting and valuable illustrations of the danger of drawing incorrect conclusions from field-culture experiments conducted for a short time only and without comprehensive knowledge of the factors involved. Thus, the first year the effect of potassium ($5.06) was four times, and that of nitrogen ($12.93) ten times as great as the effect of phosphorus ($1.33); whereas in the last

year the effect of phosphorus ($11.49) was eleven times that of potassium ($1.06), while commercial nitrogen applied in addition to the crop residues appears to have been detrimental. These facts only support the following statement quoted on page 208 of Bulletin 123, "The Fertility in Illinois Soils":

"In considering the general subject of culture experiments for determining fertilizer needs, emphasis must be laid on the fact that such experiments should never be accepted as the sole guide in determining future agricultural practice. If the culture experiments and the ultimate chemical analysis of the soil agree in the deficiency of any plant-food element, then the information is conclusive and final; but if these two sources of information disagree, then the culture experiments should be considered as tentative and likely to give way with increasing knowledge and improved methods to the information based on chemical analysis, which is absolute."[1]

THE SUBSURFACE AND SUBSOIL

In Tables 10 and 11 are recorded the amounts of plant food in the subsurface and the subsoil, but it should be remembered that these supplies are of little value unless the top soil is kept rich. Probably the most important information contained in these tables is that the most valuable upland timber soil (yellow-gray silt loam) is usually more strongly acid in the subsurface and the subsoil than in the surface, thus emphasizing the importance of having plenty of limestone in the surface soil to neutralize the acid moisture which rises from the lower strata by capillary action during times of partial drouth, which are critical periods in the life of such plants as clover. Thus, while the common brown silt loam prairie soil is practically neutral, the upland timber soil of similar topography is already in need of limestone; and, as already explained, it is much more deficient in phosphorus and nitrogen than is the common prairie soil.

[1]Taken from "Culture Experiments for Determining Fertilizer Needs," by C. G. H. in Cyclopedia of American Agriculture, Volume I, page 475.

TABLE 10.—FERTILITY IN THE SOILS OF KNOX COUNTY

Average pounds per acre in 4 million pounds[1] of subsurface (about 6⅔ to 20 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone requir'd
	Upland Prairie Soils								
526	Brown silt loam	82 720	6 900	1 960	66 060	22 590	22 880		120
520	Black clay loam	87 220	7 240	2 680	61 960	29 040	41 760		40
528	Brown gray silt loam on tight clay....	39 720	3 320	1 480	71 280	22 080	18 360		440
	Upland Timber Soils								
534	Yellow-gray silt loam	16 830	2 210	1 420	6 7550	18 740	14 650		2 240
535	Yellow silt loam	16 900	1 870	1 610	7 4860	23 140	14 340		1 300
532	Light gray silt loam on tight clay	20 400	1 920	1 920	7 4760	23 920	17 360		720
	Swamp and Bottom-Land Soils								
1326	Deep brown silt loam..	81 370	6 390	2 720	73 150	21 730	22 470		90
1301	Deep peat.....	511 440	38 420	2 480	3 200	14 260	362 920	777 780	
1303	Shallow peat on clay.......	238 180	22 180	4 100	23 900	20 740	57 100	31 140	

[1]In 2 million pounds of peat (1301 and 1303).

TABLE 11.—FERTILITY IN THE SOILS OF KNOX COUNTY

Average pounds per acre in 6 million pounds[1] of subsoil (about 20 to 40 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Lime stone requir'd
	Upland Prairie Soils								
526	Brown silt loam	35 160	3 630	2 490	99 890	47 110	35 510		250
520	Black clay loam	25 410	2 490	4 050	100 200	51 690	58 290	19 290	
528	Brown-gray silt loam on tight clay..........	39 000	3 300	2 820	104 820	52 980	32 340		300
	Upland Timber Soils								
534	Yellow-gray silt loam.. ...	16 040	2 580	3 110	101 100	47 980	30 480		1960
535	Yellow silt loam	17 570	2 150	2 780	108 580	44 440	28 940	rarely	often
532	Light gray silt loam on tight clay..........	28 080	2 460	3 720	112 440	48 600	34 920		720
	Swamp and Bottom-Land Soils								
1326	Deep brown silt loam..	51 080	4 180	3 520	110 860	37 740	29 500		140
1301	Deep peat	608 520	45 420	4 980	7 470	22 380	592 020	1287 750	
1303	Shallow peat on clay..........	174 420	10 440	6 720	93 540	69 180	384 540	724 020	

[1]In 3 million pounds of deep peat (1301).

INDIVIDUAL SOIL TYPES

(a) UPLAND PRAIRIE SOILS

The soils of this class comprise 411.37 square miles, or 57 percent of the entire county. They are usually dark in color owing to their large organic-matter content.

The accumulation of organic matter in the prairie soils is due to the growth of prairie grasses that once covered them, and whose network of roots was protected from complete decay by imperfect aeration due to the covering of fine soil material and the moisture it contained. On the native prairies the tops of these grasses were usually burned or became almost completely decayed. From a sample of virgin sod of "blue stem," one of the most common prairie grasses, it has been determined that an acre of this soil to a depth of 7 inches contained 13½ tons of roots. Many of these roots died each year and by partial decay formed the humus of these dark prairie soils. In upland forests no such quantity of roots is found in the soil. The vegetable material consists of leaves and twigs, which fall upon the surface and either are burned by forest fires or undergo almost complete decay. There is very little chance for these to become mixed with the soil. As a result the organic-matter content has been lowered by the growth of forests until in some parts of the state a low condition of apparent equilibrium has been reached.

Brown Silt Loam (526 or 226)

This is the most important as well as the most extensive type of soil in the county. It covers an area of 402.6 square miles (257,664 acres), or 55.87 percent of the entire county.

This type is generally sufficiently rolling for fair natural surface drainage, altho tile drainage is often needed and there are some exceptions where the land is so flat as to require artificial surface drainage. Some few areas along streams are so rolling that in order to prevent washing they should be cropped only with the utmost care.

Altho the brown silt loam is normally a prairie soil, in some limited areas forests have recently extended over the dark soil. These forests consist quite largely of black walnut, with such other trees as wild cherry, hackberry, ash, hard maple, and elm. A black-walnut soil is recognized generally by farmers as being one of the best timber soils. As a rule it still contains a large amount of the organic matter that accumulated from the prairie grasses.

The surface soil, 0 to 6⅔ inches, is a brown silt loam, varying from a yellowish brown on the more rolling areas to a dark brown or black on the more nearly level or originally poorly-drained areas. The physical composition varies to some extent, but is normally a silt loam containing from 70 to 85 percent of the different grades of silt together with some sand and clay. The amount of clay usually varies from 8 to 12 percent; it increases as the type approaches the black clay loam (520) and becomes greatest in the poorly-drained level areas. The amount of sand varies from 7 to 15 percent and increases as the bottom land of the large streams is approached.

The organic-matter content varies from 3.8 to 7.25 percent in the surface soil, or from 38 to 72.5 tons per acre,—about 56 tons as an average. Where this type passes into the brown-gray silt loam on tight clay (528) or

into the yellow-gray silt loam (534), the percentage of organic matter becomes lower, but where it passes into the black clay loam it becomes higher.

The natural subsurface is represented by a stratum varying from 5 to 16 inches in thickness, being thinner on the more rolling areas and thicker on the level areas. Its physical composition varies in the same way as that of the surface soil, but it usually contains a slightly larger amount of clay. Locally it may become quite heavy, as where the type grades into black clay loam. In color it varies from a dark brown or almost black to a light brown or yellowish brown, but as a rule it becomes lighter with depth and passes gradually into the yellow subsoil. The color is due to the presence of organic matter and to the oxidation of the iron. The organic-matter content averages 3.5 percent.

The natural subsoil begins 12 to 23 inches beneath the surface and extends to an indefinite depth, but it is usually sampled to 40 inches. It varies from a yellow to a drabbish-yellow clayey silt. In the level or nearly level areas it is of a drab color mottled with yellow blotches, while in the more rolling areas better drainage has allowed higher oxidation of the iron to take place, giving the yellow to brownish-yellow color. The upper 8 to 12 inches of the subsoil usually contains more clay than the lower part, the coarser material consisting of coarse silt or fine sand. The subsoil contains about 1 percent of organic matter, and is generally pervious to water, permitting good underdrainage.

While most of this type is in fair physical condition, yet the continuous growing of corn, or corn and oats, with the burning of the corn stalks and possibly the oat stubble is reducing the organic-matter content and destroying the tilth. The soil is becoming more difficult to work; it runs together more; and aeration, granulation, absorption, and moisture movement are interfered with.

This condition of poor tilth is becoming very serious on many farms and is one of the factors that limit crop yields. The remedy is to increase the organic-matter content by plowing under crop residues, such as corn stalks, straw, clover, etc., instead of selling them from the farm or burning them, as is often done at present. The stalks should be thoroly cut up with a sharp disk or stalk cutter and turned under. Likewise the straw should be put back on the land in some practical way, either directly or in the form of manure. Clover should be one of the crops grown in the rotation, and it should be plowed under directly or as manure instead of being sold as hay, except where manure can be brought back.

The addition of fresh organic matter is of even greater importance, because of its nitrogen content and because of its power as it decays to liberate potassium from the inexhaustible supply in the soil and phosphorus from the phosphate contained in or applied to the soil.

For permanent profitable systems of farming, phosphorus should be applied liberally, and sufficient organic matter should be provided to furnish nitrogen. On the ordinary brown silt loam, limestone is already becoming deficient, but this is not always the case on the heavier phase, which is usually found near draws or in low-lying areas. In live-stock farming an application of two tons of limestone and one-half ton of fine-ground rock phosphate per acre every four years, with the return to the soil of all manure made from a rotation of corn, corn, oats, and clover, will maintain the fertility of this type, altho heavier applications of phosphate may well be made during the first two or three rotations. If grain farming is practiced, the rotation may be

wheat, corn, oats, and clover, with an extra seeding of clover as a cover crop in the wheat, to be plowed under late in the fall or the following spring for corn; and most of the crop residues, with all the clover except the seed, should also be plowed under. In either system alfalfa may be grown on a fifth field and moved every five years, the hay being fed or sold. (For results of field experiments on the brown silt loam prairie, see Tables 3 to 9.)

Black Clay Loam (520)

This type of soil represents the flat prairie (the naturally poorly-drained areas of the upper Illinois glaciation) and is sometimes called "gumbo" because of its sticky character. Its formation in these places is due to the accumulation of organic matter and to the washing in of clay and fine silt from the slightly higher adjoining lands. This type is not extensive; it occupies only 8.31 square miles (5,318 acres), or 1.15 percent of the entire area of the county. In topography it is so flat that proper drainage is one of the most difficult problems in its management.

The surface stratum is a black, granular clay loam with 7 to 8½ percent of organic matter, or an average of 78 tons per acre. The wet condition of the soil has allowed a greater accumulation of organic matter in this than in any other type of upland soil in the county.

The property of granulation is important to all soils, but it is especially so to heavy ones or those containing considerable clay, since it is by granulation that the soil is kept mellow and rendered pervious to air and water. If the granules are destroyed by puddling (as by the tramping of stock while the ground is wet), they will be formed again by freezing and thawing or by wetting and drying. These natural agencies produce "slacking," as the process is usually termed. If, however, the organic-matter or lime content becomes low, this tendency to granulate grows less and the soil becomes more difficult to work.

The subsurface stratum extends to a depth of 10 to 16 inches below the surface stratum. It differs from the surface in color, becoming lighter with depth, the lower part of the stratum passing into a drab or yellowish silty clay, and it also contains a higher percentage of clay. It is quite pervious to water, due to jointing or checking from shrinkage in times of drouth. The amount of organic matter varies from 3 to 4 percent, with an average of 3.75 percent.

The subsoil is usually a drab or dull yellow silty clay but locally it may be a yellow or clayey silt. As a rule the iron is not highly oxidized because of poor drainage and lack of aeration. The subsoil is checked and jointed, making it pervious to water and consequently easy to drain.

This type presents some variations. Here as elsewhere the boundary lines between different soil types are not always distinct, but types frequently pass from one to the other very gradually, thus giving an intermediate zone of greater or less width. Gradations between brown silt loam (526) and black clay loam (520) are very likely to occur since they are usually adjoining types. This gives a lighter phase of the black clay loam, with a smaller organic-matter content than the average, and a heavier phase of the brown silt loam, with a larger amount of organic matter than usual.

Drainage is the first requirement for this type, and because of its perviousness it underdrains well. Keeping the soil in good physical condition is very essential, and thoro drainage helps to do this to a great extent. As the organic matter is destroyed by cultivation and nitrification and as the lime-

stone is removed by cropping and leaching, the physical condition of the soil becomes poorer, and consequently it becomes more difficult to work. Both organic matter and lime tend to develop granulation. The former should be maintained by turning under manure, clover, and crop residues, such as cornstalks and straw, instead of burning them as is so commonly practiced. Ground limestone should be applied when needed to keep the soil sweet.

While this type of soil is one of the best in the state, yet the clay and humus contained in it give it the property of shrinkage and expansion to such a degree as to be somewhat objectionable at times, especially during drouth. When the soil is wet these constituents expand, and when the moisture evaporates or is used by crops, the soil shrinks. The result is the formation of cracks up to two inches or more in width and extending with lessening width a foot or more in depth. These cracks permit the excessive loss of moisture from the surface, subsurface, and subsoil. They also sometimes "block out" the hills of corn, tearing the roots and doing considerable damage to the crop. While cracking may not be prevented entirely, yet good tilth with a soil mulch will do much toward that end.

This type is well supplied with plant food, which is usually liberated with sufficient rapidity by a good rotation and the addition of moderate amounts of organic matter. The amount of organic matter added must be increased, of course, with continued farming until the nitrogen supplied is equal to that removed. While no marked profit is to be expected from the addition of phosphorus, it is likely to pay its cost in the second or third rotation, and even by maintaining the productive power of the land the capital invested is protected. This soil is rich in magnesium and calcium, and the subsoil usually contains plenty of carbonates. With continued cropping and leaching, the addition of limestone will be necessary. (No field experiments have been conducted as yet on this type of soil.)

Brown-Gray Silt Loam on Tight Clay (528)

This type occupies only .46 square mile (295 acres), or only .06 percent of the area of the county. It occurs almost entirely in areas intermediate between the prairie brown silt loam (526) and the timber yellow-gray silt loam (5.34). In topography it is usually flat.

The surface soil, 0 to 6⅔ inches, is a light brown to a grayish-brown silt loam, containing some fine sand and coarse silt that gives it a peculiar mealy "feel." The organic matter varies from 3½ to 4 percent according to the relation of this type to other types, being greater where it approaches brown silt loam and less where it passes into yellow-gray silt loam (534).

The subsurface is represented by a stratum of silt loam 10 to 12 inches thick, which varies in color from brown to gray, usually from the upper to the lower parts of the stratum. It differs from the surface in containing less organic matter, the average percentage being but 1.7.

The subsoil is a yellowish clay, beginning 16 to 18 inches beneath the surface. This clay stratum is not so nearly impervious as that of the corresponding type in southern Illinois.

This type should be drained where necessary. Care should be taken to increase the nitrogen and the organic-matter content by proper rotation and by turning under crop residues, clover, or farm manure. Phosphorus should be used liberally in connection with the decaying organic matter, as on the brown silt loam, and limestone should also be applied at the rate of 2 to 3 tons per acre every four to six years.

(b) Upland Timber Soils

Yellow-Gray Silt Loam (534 *or* 234)

This type occurs in the outer timber belts along the streams and covers 104.44 square miles (66,842 acres), or 14½ percent of the entire county. In topography it is sufficiently rolling for good surface drainage without much tendency to wash if proper care is taken.

The surface soil, 0 to 6⅔ inches, is a gray to yellowish-gray silt loam, incoherent and mealy, but not granular. The amount of organic matter averages about 2.2 percent, or 22 tons per acre.

The subsurface stratum varies from 3 to 10 inches in thickness. The greatest variation is due to topography, the thinner subsurface being on the more rolling land. It is a silt loam, gray, grayish-yellow, or yellow in color, somewhat mealy but becoming more coherent and clayey with depth, and containing only .72 percent of organic matter.

The subsoil is a yellow or grayish-yellow mottled clayey silt or silty clay, somewhat plastic when wet but friable when moist, and pervious to water.

This type is quite variable in texture because of the fact that it grades into so many different types, the transition zone between two types showing a likeness to each.

Agriculturally, the yellow-gray silt loam in Knox county is second in importance, but with the improvements easily possible its value per acre may become equal to that of the brown silt loam. In the management of this type, one of the first essentials is the maintenance or increase of the organic matter in order to give better tilth, to supply nitrogen and liberate mineral plant food, to prevent running together, and in some of the more rolling phases to prevent washing. Another essential is the application of ground limestone, especially in order that clover, alfalfa, and other legumes may be grown more successfully. Liberal use should also be made of phosphorus, since in the surface stratum of this type there is less than 900 pounds to an acre. (See Table 2, page 5.)

For definite results from the most practical field experiments upon typical yellow-gray silt loam, we must go down into "Egypt," where the people of Saline county, especially those in the vicinity of Raleigh and Galatia, have provided the University with a very suitable tract of this type of soil for a permanent experiment field. There, as an average of triplicate tests each year, the yield of corn on untreated land was 25.3 bushels in 1910, 23.6 bushels in 1911, and 22 bushels in 1912; while the corresponding averages from land treated with heavy applications of limestone and a limited amount of organic manures were 41.4 bushels in 1910, 41.3 bushels in 1911, and 50.1 bushels in 1912, the corn being grown on a different series of plots every year in a four-year rotation of wheat, corn, oats, and clover. About the same proportionate increases were produced in wheat and hay, and the effect on oats was also marked.

Owing to the low supply of organic matter and limestone, phosphorus produced no benefit, as an average, during the first two years, but with increasing supplies of organic matter the effect of phosphorus is seen in the crops of 1912 and 1913. Of course, a single four-year rotation cannot be practiced in less than four years, and the full benefit of the system of rotation and soil treatment is not to be expected before the third or fourth four-year period.

While limestone is the material first needed for the economic improvement of the more acid soil of southern Illinois, with organic manures and phosphorus to follow in order, the less acid soils of the central and northern parts of the state are frequently most deficient, relatively, in phosphorus and organic matter.

Table 12 shows in detail eleven years' results secured from the Antioch soil experiment field located in Lake county on the yellow-gray silt loam of the late Wisconsin glaciation. In acidity, this type in Knox county is intermediate between the similar soils in Saline and Lake counties, but no experiment field has been conducted on this important soil type in the upper Illinois glaciation.

The Antioch field was started in order to learn as quickly as possible just what effect would be produced by the addition of nitrogen, phosphorus, and potassium, singly and in combination. These elements have all been added in commercial form. Only a small amount of lime was applied at the beginning, and with the abnormality of Plot 1 and with an abundance of limestone in the subsoil (a common condition in the late Wisconsin glaciation), no conclusions can be drawn regarding the effect of lime.

As an average of 44 tests (4 each year for 11 years), liberal applications of commercial nitrogen produced a slight decrease in crop values, phosphorus paid back 200 percent of its cost, while each dollar invested in potassium brought back only 34 cents (a net loss of 66 percent). Thus, while the detailed data show great variation, owing both to some irregularity of soil and to some very abnormal seasons, with three almost complete crop failures (1904, 1907, and 1910), yet the general summary strongly confirms the analytical data in showing the need of applying phosphorus and the profit from its use, and the loss in adding potassium. In most cases commercial nitrogen damaged the small grains by causing the crop to lodge; but whenever a corn yield of 40 bushels or more was secured where phosphorus had been applied either alone or with potassium, then the addition of nitrogen produced an increase. From a comparison of the results from the Sibley and the Bloomington fields, we must conclude that better yields are to be secured by providing nitrogen by means of legume crops grown in the rotation rather than by the use of commercial nitrogen, which is evidently too readily available, causing too rapid growth and consequent weakness of straw; and of course the atmosphere is the most economic source of nitrogen where that element is needed for soil improvement in general farming. (See Appendix for detailed discussion of "Permanent Soil Improvement.")

Yellow Silt Loam (535 *or* 235)

This type covers about 133.71 square miles (85,574 acres), or 18.56 percent of the entire county. It occurs as the hilly and badly eroded lands on the inner timber belts along streams, usually only in narrow, irregular strips with arms extending up the small streams. In topography it is very rolling and so badly broken that as a rule it should not be cultivated because of the danger of injury from washing.

The surface soil, 0 to 6⅔ inches, is a yellow or grayish-yellow mealy silt loam. It varies a great deal because of recent washing; in some places the real subsoil may be exposed. The amount of organic matter varies from 1.5 to 3 percent depending upon the extent of the washing, but it averages about 2.2 percent, or 22 tons per acre.

TABLE 12.—CROP YIELDS IN SOIL EXPERIMENTS, ANTIOCH FIELD

Plot	Yellow-gray silt loam, undulating timber-land; late Wisconsin glaciation Soil treatment applied	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912
		Bushels per acre										
101	None[1]	44.8	36.6	17.8	18.5	35.9	12.4	65.6	12.2	5.2	34.4	21.3
102	Lime	45.1	38.9	12.8	10.3	31.5	9.5	61.6	11.7	3.0	24.6	17.5
103	Lime, nitrogen	46.3	40.8	2.8	17.8	37.8	6.4	60.3	13.0	1.4	10.4	24.4
104	Lime, phosphorus	50.1	53.6	12.5	35.8	57.4	13.4	70.9	23.3	6.8	37.4	49.1
105	Lime, potassium	48.2	50.2	9.7	21.7	34.9	12.9	62.5	13.5	4.6	20.4	18.8
106	Lime, nitro., phos.	56.6	62.7	15.9	15.2	59.3	20.9	49.1	33.8	6.0	37.0	46.9
107	Lime, nitro., potas.	52.1	54.9	10 3	11.8	39.0	11.1	52.6	21.0	1.6	7.0	16.9
108	Lime, phos., potas.	60.7	66.0	19.7	28.7	59.1	18.3	59.4	26.2	3.2	42.2	35.9
109	Lime, nitro., phos. potas.	61.2	69.1	31.9	18.0	65.9	31.4	51.9	30.5	3.0	44.2	31.9
110	Nitro., phos., potas.	59.7	71.8	37.2	16.3	66.3	28.8	55.9	34.5	4.0	49.0	38.1

Average Increase: Bushels per Acre

	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912
For nitrogen	3.0	4.7	1.6	−8.4	4.8	3.9	−10.1	5.9	−1.4	−6.5	−.3
For phosphorus	9.2	16.7	11.1	9.0	24.6	11.0	−1.4	13.7	2.1	24.6	21.6
For potassium	6.0	11.0	6.9	.3	3.2	5.9	−3.9	2.3	−1.2	1.1	−8.6
For nitro., phos. over phos.	6.5	9.1	3.4	−20.6	1.9	7.5	−21.8	10.5	−.8	−.4	2.2
For phos., nitro. over nitro.	10.3	21.9	13.1	−2.6	21.5	14.5	−11.2	20.8	4.6	26.6	22.5
For potas., nitro., phos. over nitro., phos.	4.6	6.4	16.0	2.8	6.6	10.5	2.8	−3.3	−3.0	7.2	−15.0

Value of Crops per Acre in Eleven Years

Plot	Soil treatment applied	Total value of eleven crops	Value of increase
101	None	$112.16	
102	Lime	96.38	$−15.78
103	Lime, nitrogen	97.89	−14.27
104	Lime, phosphorus	157.67	45.51
105	Lime, potassium	111.86	−.30
106	Lime, nitrogen, phosphorus	152.75	40.59
107	Lime, nitrogen, potassium	104.89	−7.27
108	Lime, phosphorus, potassium	160.25	48.09
109	Lime, nitrogen, phosphorus, potassium	164.83	52.67
110	Nitrogen, phosphorus, potassium	172.78	60.62

Value of Increase per Acre in Eleven Years		Cost of increase
For nitrogen	$1.51	$165.00
For phosphorus	61.29	27.50
For *nitrogen* and phosphorus over phosphorus	−4.92	165.00
For *phosphorus* and nitrogen over nitrogen	54.86	27.50
For *potassium*, nitrogen, and phosphorus over nitrogen and phosphorus	12.08	27.50

[1]Plot 101, the check plot, is the lowest ground but it is well drained and is appreciably better land than the rest of the field. Plot 102 is a more trustworthy check plot.

The subsurface varies from 0 to 12 inches in thickness on account of the removal of part or all of the surface and subsurface by washing.

The subsoil is a compact yellow clayey silt which in some places may consist of glacial drift brought near the surface by erosion.

In the management of this type, the most important thing is to prevent general surface washing and gullying. If it is cropped at all, a rotation should be practiced that will require a cultivated crop as little as possible and allow pasture and meadow most of the time. If tilled, the land should be plowed deeply, and contours should be followed as nearly as possibly both in plowing and in planting. Furrows should not be made extending up and down the slope, and the land should be cultivated in the same direction in which it is plowed. Every means should be employed to maintain and to increase the organic-matter content in order to supply nitrogen and to help hold the soil and keep it in good physical condition so that it will absorb a large amount of water and thus diminish the run-off. (See Circular 119.)

Additional treatment recommended is the liberal use of ground limestone. This is advised only where surface erosion has not occurred to too great an extent, and chiefly for such crops as clover and alfalfa, which can often be produced successfully with plenty of limestone (5 tons per acre), thoro inoculation, and about 10 tons of farm manure to give the young alfalfa a good start, after which its extensive root system makes the plant almost independent of the surface soil, except for limestone. An initial application of 500 pounds per acre of steamed bone meal or acid phosphate is often helpful in starting alfalfa, especially where manure is not available.

Light Gray Silt Loam on Tight Clay (532)

Only two very small areas of this type, aggregating but 12 acres, are shown on the map. Many others occur, but they are too small to be represented on a map of this scale.

The surface soil is a white or light gray silt loam, incoherent, mealy, and porous. Spherical iron concretions are usually present. The organic-matter content is low, amounting to only about 2.2 percent, or 22 tons per acre.

The subsurface is a light gray silt extending to a depth of 14 to 18 inches, becoming more clayey with depth and containing only .7 percent of organic matter.

The subsoil is a tight, compact, plastic, clayey silt, yellow with gray mottlings.

Besides being deficient in organic matter, this type is lacking in limestone and is consequently in poor physical condition. It runs together badly and, owing to the strong capillarity in the surface and subsurface strata, it does not hold moisture well. In the management of this soil, ground limestone should be used liberally, rock phosphate should be added, and the organic-matter content increased in every practical way. Deep-rooting crops, such as red, mammoth, or sweet clover, would loosen the tight clay subsoil as well as supply the soil with organic matter and nitrogen. Crop residues or farm manure should be plowed under to bring the soil into better tilth.

(c) SWAMP AND BOTTOM-LAND SOILS

Deep Brown Silt Loam (1326)

The bottom-land soil is derived from material washed from the upland, and must therefore have some relation to the upland soils. It differs in being more variable in physical composition than any single upland type, and the brown color extends into it to greater depth. The bottoms along the streams of the county vary from a few rods to a mile or more in width. These lands occupy 71.09 square miles (45,498 acres), and constitute 9.86 percent of the entire area of the county. In topography they are flat or have very slight undulations that represent old stream or overflow channels. Better drainage is needed in much of this area.

The surface soil, 0 to 6⅔ inches, is usually a brown silt loam containing from 3.5 to 5.3 percent of organic matter, the average being 4.4 percent, or 44 tons per acre. It is probably easier to maintain the fertility and the organic matter in this type than in the upland types, because of occasional overflow and the consequent deposition of material rich in humus and plant food. In physical composition this soil varies from a clay loam to a sandy loam, but the areas of these extreme types, especially of the sandy loam, are so small and so changeable that it is impracticable to try to show them on the map, as the next flood may change their boundaries.

The subsurface is brown silt loam, becoming lighter in color and frequently in texture with depth. It contains an average of 3.2 percent of organic matter.

The subsoil is a yellowish-drab silt loam varying in physical composition either to a clayey silt or to a sandy loam, or even to a sand in the lower subsoil. Because of the way in which this type was formed, the different strata necessarily vary greatly.

Where proper drainage is secured the type is quite productive. As a rule, where it is subject to frequent overflow nothing is needed except good farming. Even the systematic rotation of crops is not so important where the land is subject to occasional overflows, but where it lies high or is protected from overflow a rotation including legume crops should be practiced, and ultimately provision should be made for the enrichment of such protected land in both phosphorus and organic matter, and if necessary in limestone.

Deep Peat (1301)

A small area of deep peat, covering about 26 acres, is found in Section 1, Township 9 North, Range 3 East. This area needs drainage first of all. The surface soil, 0 to 6⅔ inches, is a brown somewhat marly peat, varying in composition because of silts carried in and deposited by water. Both subsurface and subsoil are brown peat mixed with shells.

The samples collected and analyzed show great deficiency in potassium and only moderate amounts of phosphorus. The addition of 100 to 200 pounds per acre of potassium chlorid (often erroneously called "muriate" of potash) is almost certain to produce very marked benefit; and where this is done, phosphorus is likely to prove profitable in the future. When manure is applied, it will furnish potassium and produce increased crops, as a rule, but if the supply of manure is limited, it may be a better plan to use it on other

land, and improve this with commercial materials. (See also Bulletin 157, "Peaty Swamp Lands; Sand and 'Alkali' Soils.")

Shallow Peat on Clay (1303)

This type occupies an area of about 19 acres in the southwest quarter of Section 7, Township 9 North, Range 3 East, on the edge of the bottom land. It includes some medium peat, but shallow peat predominates.

The surface soil, 0 to 6⅔ inches, is a brown peat containing some shells.

The subsurface consists of a stratum of brown peat varying from 4 to 10 inches in thickness underlain by a drab clay that constitutes the subsoil.

Aside from drainage, very deep plowing, which will mix some of the clay with the peaty stratum, is the only special treatment recommended. (See Bulletin 157 for results of such plowing on similar land.)

APPENDIX

A study of the soil map and the tabular statements concerning crop requirements, the plant-food content of the different soil types, and the actual results secured from definite field trials with different methods or systems of soil improvement, and a careful study of the discussion of general principles and of the descriptions of individual soil types, will furnish the most necessary and useful information for the practical improvement and permanent preservation of the productive power of every kind of soil on every farm in the county.

More complete information concerning the most extensive and important soil types in the great soil areas in all parts of Illinois is contained in Bulletin 123, "The Fertility in Illinois Soils," which contains a colored general survey soil map of the entire state.

Other publications of general interest are:

Bulletin No. 76, "Alfalfa on Illinois Soils"
Bulletin No. 94, "Nitrogen Bacteria and Legumes"
Bulletin No. 115, "Soil Improvement for the Worn Hill Lands of Illinois"
Bulletin No. 125, "Thirty Years of Crop Rotation on the Common Prairie Lands of Illinois"
Circular No. 110, "Ground Limestone for Acid Soils"
Circular No. 127, "Shall we use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils?"
Circular No. 129, "The Use of Commercial Fertilizers"
Circular No. 149, "Some Results of Scientific Soil Treatment" and "Methods and Results of Ten Years' Soil Investigation in Illinois"
Circular No. 165, "Shall we use 'Complete' Commercial Fertilizers in the Corn Belt?"

NOTE.—Information as to where to obtain limestone, phosphate, bone meal, and potassium salts, methods of application, etc., will also be found in Circulars 110 and 165.

SOIL SURVEY METHODS

The detail soil survey of a county consists essentially of indicating on a map the location and extent of the different soil types; and, since the value of the survey depends upon its accuracy, every reasonable means is employed to make it trustworthy. To accomplish this object three things are essential: first, careful, well-trained men to do the work; second, an accurate base map upon which to show the results of their work: and, third, the means necessary to enable the men to place the soil-type boundaries, streams, etc., accurately upon the map.

The men selected for the work must be able to keep their location exactly and to recognize the different soil types, with their principal variations and limits, and they must show these upon the maps correctly. A definite system is employed in checking up this work. As an illustration, one soil expert will survey and map a strip 80 rods or 160 rods wide and any convenient length, while his associate will work independently on another strip adjoining this area, and, if the work is correctly done, the soil type boundaries will match up on the line between the two strips.

An accurate base map for field use is absolutely necessary for soil mapping. The base maps are made on a scale of one inch to the mile. The official data of the original or subsequent land survey are used as a basis in the construction of these maps, while the most trustworthy county map available is used in locating temporarily the streams, roads, and railroads. Since the best of these published maps have some inaccuracies, the location of every road, stream, and railroad must be verified by the soil surveyors, and cor-

rected if wrongly located. In order to make these verifications and corrections, each survey party is provided with an odometer for measuring distances, and a plane table for determining directions of roads, railroads, etc.

Each surveyor is provided with a base map of the proper scale, which is carried with him in the field; and the soil-type boundaries, additional streams, and necessary corrections are placed in their proper locations upon the map while the mapper is on the area. Each section, or square mile, is divided into 40-acre plots on the map, and the surveyor must inspect every ten acres and determine the type or types of soil composing it. The different types are indicated on the map by different colors, pencils for this purpose being carried in the field.

A small auger 40 inches long forms for each man an invaluable tool with which he can quickly secure samples of the different strata for inspection. An extension for making the auger 80 inches long is taken by each party, so that any peculiarity of the deeper subsoil layers may be studied. Each man carries a compass to aid in keeping directions. Distances along roads are measured by an odometer attached to the axle of the vehicle, while distances in the field off the roads are determined by pacing, an art in which the men become expert by practice. The soil boundaries can thus be located with as high a degree of accuracy as can be indicated by pencil on the scale of one inch to the mile.

SOIL CHARACTERISTICS

The unit in the soil survey is the soil type, and each type possesses more or less definite characteristics. The line of separation between adjoining types is usually distinct, but sometimes one type grades into another so gradually that it is very difficult to draw the line between them. In such exceptional cases, some slight variation in the location of soil-type boundaries is unavoidable.

Several factors must be taken into account in establishing soil types. These are (1) the geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial, or cumulose; (2) the topography, or lay of the land; (3) the native vegetation, as forest or prairie grasses; (4) the structure, or the depth and character of the surface, subsurface, and subsoil; (5) the physical, or mechanical, composition of the different strata composing the soil, as the percentages of gravel, sand, silt, clay, and organic matter which they contain; (6) the texture, or porosity, granulation, friability, plasticity, etc.; (7) the color of the strata; (8) the natural drainage; (9) agricultural value, based upon its natural productiveness; (10) the ultimate chemical composition and reaction.

The common soil constituents are indicated in the following outline:

CONSTITUENTS OF SOILS

Soil Constituents	Organic Matter	Comprising undecomposed and partially decayed vegetable material	
	Inorganic Matter	Clay	.001 mm.[1] and less
		Silt	.001 mm. to .03 mm.
		Sand	.03 mm. to 1. mm.
		Gravel	1. mm. to 32 mm.
		Stones	32. mm. and over

[1] 25 millimeters equal 1 inch.
Further discussion of these constituents is given in Circular 82.

Groups of Soil Types

The following gives the different general groups of soils:

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or silt.

Peaty loams—15 to 35 percent of organic matter mixed with much sand and silt and a little clay.

Mucks—15 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 25 percent of clay, usually mixed with much silt.

Clay loams—Soils with from 15 to 25 percent of clay, usually mixed with much silt and some sand.

Silt loams—Soils with more than 50 percent of silt and less than 15 percent of clay, mixed with some sand.

Loams—Soils with from 30 to 50 percent of sand mixed with much silt and a little clay.

Sandy loams—Soils with from 50 to 75 percent of sand.

Fine sandy loams—Soils with from 50 to 75 percent of fine sand mixed with much silt and little clay.

Sands—Soils with more than 75 percent of sand.

Gravelly loams—Soils with 15 to 50 percent of gravel with much sand and some silt.

Gravels—Soils with more than 50 percent of gravel.

Stony loams—Soils containing a considerable number of stones over one inch in diameter.

Rock outcrop—Usually ledges of rock having no agricultural value.

More or less organic matter is found in nearly all the above classes.

Supply and Liberation of Plant Food

The productive capacity of land in humid sections depends almost wholly upon the power of the soil to feed the crop; and this, in turn, depends both upon the stock of plant food contained in the soil and upon the rate at which this is liberated, or rendered soluble and available for use in plant growth. Protection from weeds, insects, and fungous diseases, tho exceedingly important, is not a positive but a negative factor in crop production.

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but the rate of liberation is governed by many factors, some of which may be controlled by the farmer, while others are largely beyond his control. Chief among the important controllable factors which influence the liberation of plant food are limestone and decaying organic matter, which may be added to the soil by direct application of ground limestone and farm manure. Organic matter may be supplied also by green-manure crops and crop residues, such as clover, cowpeas, straw, and cornstalks. The rate of decay of organic matter depends largely upon its age and origin, and it may be hastened by tillage. The chemical analysis shows correctly the total organic carbon, which represents, as a rule, but little more than half the organic matter; so that 20,000 pounds of organic carbon in the plowed soil of an acre correspond to nearly

20 tons of organic matter. But this organic matter consists largely of the old organic residues that have accumulated during the past centuries because they were resistant to decay, and 2 tons of clover or cowpeas plowed under may have greater power to liberate plant food than the 20 tons of old, inactive organic matter. The recent history of the individual farm or field must be depended upon for information concerning recent additions of active organic matter, whether in applications of farm manure, in legume crops, or in grass-root sods of old pastures.

Probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that with the normal rainfall of Illinois the productive power of the land depends primarily upon the stock of plant food contained in the soil and upon the rate at which it is liberated, just as the success of the merchant depends primarily upon his stock of goods and the rapidity of sales. In both cases the stock of any commodity must be increased or renewed whenever the supply of such commodity becomes so depleted as to limit the success of the business, whether on the farm or in the store.

As the organic matter decays, certain decomposition products are formed, including much carbonic acid, some nitric acid, and various organic acids, and these have power to act upon the soil and dissolve the essential mineral plant foods, thus furnishing soluble phosphates, nitrates, and other salts of potassium, magnesium, calcium, etc., for the use of the growing crop.

As already explained, fresh organic matter decomposes much more rapidly than the old humus, which represents the organic residues most resistant to decay and which consequently has accumulated in the soil during the past centuries. The decay of this old humus can be hastened both by tillage, which maintains a porous condition and thus permits the oxygen of the air to enter the soil more freely and to effect the more rapid oxidation of the organic matter, and also by incorporating with the old, resistant residues some fresh organic matter, such as farm manure, clover roots, etc., which decay rapidly and thus furnish or liberate organic matter and inorganic food for bacteria, the bacteria, under such favorable conditions, appearing to have power to attack and decompose the old humus. It is probably for this reason that peat, a very inactive and inefficient fertilizer when used by itself, becomes much more effective when incorporated with fresh farm manure; so that, when used together, two tons of the mixture may be worth as much as two tons of manure, but if applied separately, the peat has little value. Bacterial action is also promoted by the presence of limestone.

The condition of the organic matter of the soil is indicated more or less definitely by the ratio of carbon to nitrogen. As an average, the fresh organic matter incorporated with soils contains about twenty times as much carbon as nitrogen, but the carbohydrates ferment and decompose much more rapidly than the nitrogenous matter; and the old resistant organic residues, such as are found in normal subsoils, commonly contain only five or six times as much carbon as nitrogen. Soils of normal physical composition, such as loam, clay loam, silt loam, and fine sandy loam, when in good productive

condition, contain about twelve to fourteen times as much carbon as nitrogen in the surface soil; while in old, worn soils that are greatly in need of fresh, active, organic manures, the ratio is narrower, sometimes falling below ten of carbon to one of nitrogen. (Except in newly made alluvial soils, the ratio is usually narrower in the subsurface and subsoil than in the surface stratum.)

It should be kept in mind that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all agricultural plants, only one (hydrogen) from water, and seven from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes), in case the amount liberated from the soil is insufficient; but even these plants (which include only the clovers, peas, beans, and vetches, among our common agricultural plants) secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron and sulfur), and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Plants are made of plant-food elements in just the same sense that a building is made of wood and iron, brick, stone, and mortar. Without materials, nothing material can be made. The normal temperature, sunshine, rainfall, and length of season in central Illinois are sufficient to produce 50 bushels of wheat per acre, 100 bushels of corn, 100 bushels of oats, and 4 tons of clover hay; and, where the land is properly drained and properly tilled, such crops would frequently be secured *if the plant foods were present in sufficient amounts and liberated at a sufficiently rapid rate to meet the absolute needs of the crops.*

CROP REQUIREMENTS

The accompanying table shows the requirements of such crops for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally in sufficient abundance compared with the amounts needed by plants, so that they are not known ever to limit the yield of general farm crops grown under normal conditions.)

TABLE A.—PLANT FOOD IN WHEAT, CORN, OATS, AND CLOVER

Produce: Kind	Produce: Amount	Nitrogen, pounds	Phosphorus, pounds	Potassium, pounds	Magnesium, pounds	Calcium, pounds
Wheat, grain	50 bu.	71	12	13	4	1
Wheat straw	2½ tons	25	4	45	4	10
Corn, grain	100 bu.	100	17	19	7	1
Corn stover	3 tons	48	6	52	10	21
Corn cobs	½ ton	2		2		
Oats, grain	100 bu.	66	11	16	4	2
Oat straw	2½ tons	31	5	52	7	15
Clover seed	4 bu.	7	2	3	1	1
Clover hay	4 tons	160	20	120	31	117
Total in grain and seed		244[1]	42	51	16	4
Total in four crops		510[1]	77	322	68	168

[1]These amounts include the nitrogen contained in the clover seed or hay, which, however, may be secured from the air.

To be sure, these are large yields, but shall we try to make possible the production of yields only half or a quarter as large as these, or shall we set as our ideal this higher mark, and then approach it as nearly as possible with profit? Among the four crops, corn is the largest, with a total yield of more than six tons per acre; and yet the 100-bushel crop of corn is often produced on rich pieces of land in good seasons. In very practical and profitable systems of farming, the Illinois Experiment Station has produced, as an average of the six years 1905 to 1910, a yield of 87 bushels of corn per acre in grain farming (with limestone and phosphorus applied, and with crop residues and legume crops turned under), and 90 bushels per acre in live-stock farming (with limestone, phosphorus, and manure).

The importance of maintaining a rich surface soil cannot be too strongly emphasized. This is well illustrated by data from the Rothamsted Experiment Station, the oldest in the world. Thus on Broadbalk field, where wheat has been grown since 1844, the average yields for the ten years 1892 to 1901 were 12.3 bushels per acre on Plot 3 (unfertilized) and 31.8 bushels on Plot 7 (well fertilized), but the amounts of both nitrogen and phosphorus in the subsoil (9 to 27 inches) were distinctly greater in Plot 3 than in Plot 7, thus showing that the higher yields from Plot 7 were due to the fact that the plowed soil had been enriched. In 1893 Plot 7 contained per acre in the surface soil (0 to 9 inches) about 600 pounds more nitrogen and 900 pounds more phosphorus than Plot 3. Even a rich subsoil has little value if it lies beneath a worn-out surface.

Methods of Liberating Plant Food

Limestone and decaying organic matter are the principal materials the farmer can utilize most profitably to bring about the liberation of plant food.

The limestone corrects the acidity of the soil and thus encourages the development not only of the nitrogen-gathering bacteria which live in the nodules on the roots of clover, cowpeas, and other legumes, but also the nitrifying bacteria, which have power to transform the insoluble and unavailable organic nitrogen into soluble and available nitrate nitrogen.

At the same time, the products of this decomposition have power to dissolve the minerals contained in the soil, such as potassium and magnesium, and also to dissolve the insoluble phosphate and limestone which may be applied in low-priced forms.

Tillage, or cultivation, also hastens the liberation of plant food by permitting the air to enter the soil and burn out the organic matter; but it should never be forgotten that tillage is wholly destructive, that it adds nothing whatever to the soil, but always leaves the soil poorer. Tillage should be practiced so far as is necessary to prepare a suitable seed-bed for root development and also for the purpose of killing weeds, but more than this is unnecessary and unprofitable in seasons of normal rainfall; and it is much better actually to enrich the soil by proper applications or additions, including limestone and organic matter (both of which have power to improve the physical condition as well as to liberate plant food) than merely to hasten soil depletion by means of excessive cultivation.

Permanent Soil Improvement

The best and most profitable methods for the permanent improvement of the common soils of Illinois are as follows:

(1) If the soil is acid, apply at least two tons per acre of ground limestone, preferably at times magnesian limestone ($CaCO_3MgCO_3$), which contains both calcium and magnesium and has slightly greater power to correct soil acidity, ton for ton, than the ordinary calcium limestone ($CaCO_3$); and continue to apply about two tons per acre of ground limestone every four or five years. On strongly acid soils, or in preparing the land for alfalfa, five tons per acre of ground limestone may well be used for the first application.

(2) Adopt a good rotation of crops, including a liberal use of legumes, and increase the organic matter of the soil either by plowing under the legume crops and other crop residues (straw and corn stalks), or by using for feed and bedding practically all the crops raised and returning the manure to the land with the least possible loss. No one can say in advance what will prove to be the best rotation of crops, because of variation in farms and farmers, and in prices for produce, but the following are suggested to serve as models or outlines:

First year, corn.
Second year, corn.
Third year, wheat or oats (with clover or clover and grass).
Fourth year, clover or clover and grass.
Fifth year, wheat and clover or grass and clover.
Sixth year, clover or clover and grass.

Of course there should be as many fields as there are years in the rotation. In grain farming, with small grain grown the third and fifth years, most of the coarse products should be returned to the soil, and the clover may be clipped and left on the land (only the clover seed being sold the fourth and sixth years); or, in live-stock farming, the field may be used three years for timothy and clover pasture and meadow if desired. The system may be reduced to a five-year rotation by cutting out either the second or the sixth year, and to a four-year system by omitting the fifth and sixth years.

With two years of corn, followed by oats with clover-seeding the third year, and by clover the fourth year, all produce can be used for feed and bedding if other land is available for permanent pasture. Alfalfa may be grown on a fifth field for four or eight years, which is to be alternated with one of the four; or the alfalfa may be moved every five years, and thus rotated over all five fields every twenty-five years.

Other four-year rotations more suitable for grain farming are:

Wheat (and clover), corn, oats, and clover; or corn (and clover), cowpeas, wheat, and clover. (Alfalfa may be grown on a fifth field and rotated every five years, the hay being sold.)

Good three-year rotations are:

Corn, oats, and clover; corn, wheat, and clover; or wheat (and clover), corn (and clover), and cowpeas, in which two cover crops and one regular crop of legumes are grown in three years.

A five-year rotation of (1) corn (and clover), (2) cowpeas, (3) wheat, (4) clover, and (5) wheat (and clover) allows legumes to be seeded four times, and alfalfa may be grown on a sixth field for five or six years in the combination rotation, alternating between two fields every five years, or rotating over all the fields if moved every six years.

To avoid clover sickness it may sometimes be necessary to substitute sweet clover or alsike for red clover in about every third rotation, and at the same

time to discontinue its use in the cover-crop mixture. If the corn crop is not too rank, cowpeas or soybeans may also be used as a cover crop (seeded at the last cultivation) in the southern part of the state, and, if necessary to avoid disease, these may well alternate in successive rotations.

For easy figuring it may well be kept in mind that the following amounts of nitrogen are required for the produce named:

1 bushel of oats (grain and straw) requires 1 pound of nitrogen.
1 bushel of corn (grain and stalks) requires 1½ pounds of nitrogen.
1 bushel of wheat (grain and straw) requires 2 pounds of nitrogen.
1 ton of timothy requires 24 pounds of nitrogen.
1 ton of clover contains 40 pounds of nitrogen.
1 ton of cowpeas contains 43 pounds of nitrogen.
1 ton of average manure contains 10 pounds of nitrogen.

The roots of clover contain about half as much nitrogen as the tops, and the roots of cowpeas contain about one-tenth as much as the tops.

Soils of moderate productive power will furnish as much nitrogen to clover (and two or three times as much to cowpeas) as will be left in the roots and stubble. For grain crops, such as wheat, corn, and oats, about two-thirds of the nitrogen is contained in the grain and one-third in the straw or stalks. (See also discussion of "The Potassium Problem," on pages below.)

(3) On all lands deficient in phosphorus (except on those susceptible to serious erosion by surface washing or gullying) apply that element in considerably larger amounts than are required to meet the actual needs of the crops desired to be produced. The abundant information thus far secured shows positively that fine-ground natural rock phosphate can be used successfully and very profitably, and clearly indicates that this material will be the most economical form of phosphorus to use in all ordinary systems of permanent, profitable soil improvement. The first application may well be one ton per acre, and subsequently about one-half ton per acre every four or five years should be applied, at least until the phosphorus content of the plowed soil reaches 2,000 pounds per acre, which may require a total application of from three to five or six tons per acre of raw phosphate containing 12½ percent of the element phosphorus.

Steamed bone meal and even acid phosphate may be used in emergencies, but it should always be kept in mind that phosphorus delivered in Illinois costs about 3 cents a pound in raw phosphate (direct from the mine in carload lots), but 10 cents a pound in steamed bone meal, and about 12 cents a pound in acid phosphate, both of which cost too much per ton to permit their common purchase by farmers in carload lots, which is not the case with limestone or raw phosphate.

Phosphorus once applied to the soil remains in it until removed in crops, unless carried away mechanically by soil erosion. (The loss by leaching is only about 1½ pounds per acre per annum, so that more than 150 years would be required to leach away the phosphorus applied in one ton of raw phosphate.)

The phosphate and limestone may be applied at any time during the rotation, but a good method is to apply the limestone after plowing and work it into the surface soil in preparing the seed bed for wheat, oats, rye, or barley, where clover is to be seeded; while phosphate is best plowed under with farm manure, clover, or other green manures, which serve to liberate the phosphorus.

(4) Until the supply of decaying organic matter has been made adequate, on the poorer types of upland timber and gray prairie soils some temporary benefit may be derived from the use of a soluble salt or mixture of salts, such as kainit, which contains both potassium and magnesium in soluble form and also some common salt (sodium chlorid). About 600 pounds per acre of kainit applied and turned under with the raw phosphate will help to dissolve the phosphorus as well as to furnish available potassium and magnesium, and for a few years such use of kainit will no doubt be profitable on lands deficient in organic matter, but the evidence thus far secured indicates that its use is not absolutely necessary and that it will not be profitable after adequate provision is made for decaying organic matter, since this will necessitate returning to the soil either all produce except the grain (in grain farming) or the manure produced in live-stock farming. (Where hay or straw is sold, manure should be bought.)

On soils which are subject to surface washing, including especially the yellow silt loam of the upland timber area, and to some extent the yellow-gray silt loam, and other more rolling areas, the supply of minerals in the subsurface and subsoil (which gradually renew the surface soil) tends to provide for a low-grade system of permanent agriculture if some use is made of legume plants, as in long rotations with much pasture, because both the minerals and nitrogen are thus provided in some amount almost permanently; but where such lands are farmed under such a system, not more than two or three grain crops should be grown during a period of ten or twelve years, the land being kept in pasture most of the time; and where the soil is acid a liberal use of limestone, as top-dressings if necessary, and occasional reseeding with clovers will benefit both the pasture and indirectly the grain crops.

Advantage of Crop Rotation and Permanent Systems

It should be noted that clover is not likely to be well infected with the clover bacteria during the first rotation on a given farm or field where it has not been grown before within recent years; but even a partial stand of clover the first time will probably provide a thousand times as many bacteria for the next clover crop as one could afford to apply in artificial inoculation, for a single root-tubercle may contain a million bacteria developed from one during the season's growth.

This is only one of several advantages of the second course of the rotation over the first course. Thus the mere practice of crop rotation is an advantage, especially in helping to rid the land of insects and foul grass and weeds. The deep-rooting clover crop is an advantage to subsequent crops because of that characteristic. The larger applications of organic manures (made possible by the larger crops) are a great advantage; and in systems of permanent soil improvement, such as are here advised and illustrated, more limestone and more phosphorus are provided than are needed for the meager or moderate crops produced during the first rotation, and consequently the crops in the second rotation have the advantage of such accumulated residues (well incorporated with the plowed soil) in addition to the regular applications made during the second rotation.

This means that these systems tend positively toward the making of richer lands. The ultimate analyses recorded in the tables give the absolute invoice of these Illinois soils. They show that most of them are positively deficient only in limestone, phosphorus, and nitrogenous organic matter: and

the accumulated information from careful and long-continued investigations in different parts of the United States clearly establishes the fact that in general farming these essentials can be supplied with greatest economy and profit by the use of ground natural limestone, very finely ground natural rock phosphate, and legume crops to be plowed under directly or in farm manure. On normal soils no other applications are absolutely necessary, but, as already explained, the addition of some soluble salt in the beginning of a system of improvement on some of these soils produces temporary benefit, and if some inexpensive salt, such as kainit, is used, it may produce sufficient increase to more than pay the added cost.

THE POTASSIUM PROBLEM

As reported in Illinois Bulletin 123, where wheat has been grown every year for more than half a century at Rothamsted, England, exactly the same increase was produced (5.6 bushels per acre), as an average of the first 24 years, whether potassium, magnesium, or sodium was applied, the rate of application per annum being 200 pounds of potassium sulfate and molecular equivalents of magnesium sulfate and sodium sulfate. As an average of 60 years (1852 to 1911), the yield of wheat has been 12.7 bushels on untreated land, 23.3 bushels where 86 pounds of nitrogen and 29 pounds of phosphorus per acre per annum were applied; and, as further additions, 85 pounds of potassium raised the yield to 31.3 bushels; 52 pounds of magnesium raised it to 29.2 bushels; and 50 pounds of sodium raised it to 29.5 bushels. Where potassium was applied, the average wheat crop removed 40 pounds of that element in the grain and straw, or three times as much as would be removed in the grain only for such crops as are suggested in Table A. The Rothamsted soil contained an abundance of limestone, but no organic matter was provided except the little in the stubble and roots of the wheat plants.

On another field at Rothamsted the average yield of barley for 60 years (1852 to 1911) has been 14.2 bushels on untreated land, 38.1 bushels where 43 pounds of nitrogen and 29 pounds of phosphorus have been applied per acre per annum; while the further addition of 85 pounds of potassium, 19 pounds of magnesium, and 14 pounds of sodium (all in sulfates) raised the average yield to 41.5 bushels, but, where only 70 pounds of sodium were applied in addition to the nitrogen and phosphorus, the average has been 43.0 bushels. Thus, as an average of 60 years, the use of sodium produced 1.8 bushels less wheat and 1.5 bushels more barley than the use of potassium, with both grain and straw removed and no organic manures returned.

In recent years the effect of potassium is becoming much more marked than that of sodium or magnesium, on the wheat crop; but this must be expected to occur in time where no potassium is returned in straw or manure, and no provision made for liberating potassium from the supply still remaining in the soil. If more than three-fourths of the potassium removed were returned in the straw (see Table A), and if the decomposition products of the straw have power to liberate additional amounts of potassium from the soil, the necessity of purchasing potassium in a good system of farming on such land is very remote.

While about half the potassium, nitrogen, and organic matter, and about one-fourth the phosphorus contained in manure will be lost by three or four months' exposure in the ordinary pile in the barn yard, there

is practically no loss if plenty of absorbent bedding is used on cement floors, and if the manure is hauled to the field and spread within a day or two after it is produced. Again, while the animals destroy two-thirds of the organic matter and retain one-fourth of the nitrogen and phosphorus in average live-stock farming, they retain less than one-tenth of the potassium, from the food consumed; so that the actual loss of potassium in the products sold from the farm, either in grain farming or in live-stock farming, is wholly negligible on land containing 25,000 pounds or more of potassium in the surface 6⅔ inches.

The removal of one inch of soil per century by surface washing (which is likely to occur wherever there is satisfactory surface drainage and frequent cultivation) would permanently maintain the potassium in grain farming by renewal from the subsoil, provided one-third of the potassium is removed by cropping before the soil is carried away.

From all of these facts it will be seen that the potassium problem is not one of addition but of liberation; and the Rothamsted records show that for many years other soluble salts have practically the same power as potassium to increase crop yields in the absence of sufficient decaying organic matter. Whether this action relates to supplying or liberating potassium for its own sake, or to the power of the soluble salt to increase the availability of phosphorus or other elements, is not known, but where much potassium is removed, as in the entire crops at Rothamsted, with no return of organic residues, probably the soluble salt functions in both ways.

As an average of 112 separate tests conducted in 1907, 1908, 1909, and 1910 on the Fairfield experiment field, an application of 200 pounds of potassium sulfate, containing 85 pounds of potassium and costing $5.10, increased the yield of corn by 9.3 bushels per acre: while 600 pounds of kainit, containing only 60 pounds of potassium and costing $4.00, gave an increase of 10.7 bushels. Thus, at 40 cents a bushel for corn, the kainit has paid for itself; but these results, like those at Rothamsted, were secured where no adequate provision had been made for decaying organic matter.

Additional experiments at Fairfield include an equally complete test with potassium sulfate and kainit on land to which 8 tons per acre of farm manure had been applied. As an average of 112 tests with each material, the 200 pounds of potassium sulfate increased the yield of corn by 1.7 bushels, while the 600 pounds of kainit also gave an increase of 1.7 bushels. Thus, where organic manure was supplied, very little effect was produced by the addition of either potassium sulfate or kainit; in part perhaps because the potassium removed in the crops is mostly returned in the manure if properly cared for, and perhaps in larger part because the decaying organic matter helps to liberate and hold in solution other plant-food elements, especially phosphorus.

In laboratory experiments at the Illinois Experiment Station, it has been shown that potassium salts and most other soluble salts increase the solubility of the phosphorus in soil and in rock phosphate as determined by chemical analysis; also that the addition of glucose with rock phosphate in pot-culture experiments increases the availability of the phosphorus, as measured by plant growth, altho the glucose consists only of carbon, hydrogen, and oxygen, and thus contains no plant food of value.

If we remember that, as an average, live stock destroy two-thirds of the organic matter of the food consumed, it is easy to determine from Table A

that more organic matter will be supplied in a proper grain system than in a strictly live-stock system; and the evidence thus far secured from older experiments at the University and at other places in the state indicates that if the corn stalks, straw, clover, etc., are incorporated with the soil as soon as practicable after they are produced (which can usually be done in the late fall or early spring), there is little or no difficulty in securing sufficient decomposition in our humid climate to avoid serious interference with the capillary movement of the soil moisture, a common danger from plowing under too much coarse manure of any kind in the late spring of a dry year.

If, however, the entire produce of the land is sold from the farm, as in hay farming, or when both grain and straw are sold, of course the draft on potassium will then be so great that in time it must be renewed by some sort of application. As a rule, such farmers ought to secure manure from town, since they furnish the bulk of the material out of which manure is produced.

CALCIUM AND MAGNESIUM

When measured by the actual crop requirements for plant food, magnesium and calcium are more limited in some Illinois soils than potassium. But with these elements we must also consider the loss by leaching. As an average of 90 analyses[1] of Illinois well-waters drawn chiefly from glacial sands, gravels, or till, 3 million pounds of water (about the average annual drainage per acre for Illinois) contained 11 pounds of potassium, 130 of magnesium, and 330 of calcium. These figures are very significant, and it may be stated that if the plowed soil is well supplied with the carbonates of magnesium and calcium, then a very considerable proportion of these amounts will be leached from that stratum. Thus the loss of calcium from the plowed soil of an acre at Rothamsted, England, where the soil contains plenty of limestone, has averaged more than 300 pounds a year as determined by analyzing the soil in 1865 and again in 1905. And practically the same amount of calcium was found by analyzing the Rothamsted drainage waters.

Common limestone, which is calcium carbonate ($CaCO_3$), contains, when pure, 40 percent of calcium, so that 800 pounds of limestone are equivalent to 320 pounds of calcium. Where 10 tons per acre of ground limestone were applied at Edgewood, Illinois, the average annual loss during the next ten years amounted to 790 pounds per acre. The definite data from careful investigations seem to be ample to justify the conclusion that where limestone is needed at least 2 tons per acre should be applied every 4 or 5 years.

It is of interest to note that thirty crops of clover of four tons each would require 3,510 pounds of calcium, while the most common prairie land of southern Illinois contains only 3,420 pounds of total calcium in the plowed soil of an acre. (See Soil Report No. 1.) Thus limestone has a positive value on some soils for the plant food which it supplies, in addition to its value in correcting soil acidity and in improving the physical condition of the soil. Ordinary limestone (abundant in the southern and western parts of the state) contains nearly 800 pounds of calcium per ton; while a good grade of dolomitic limestone (the more common limestone of northern Illinois) contains about 400 pounds of calcium and 300 pounds of magnesium per ton. Both of these elements are furnished in readily available form in ground dolomitic limestone.

[1]Reported by Doctor Bartow and associates, of the Illinois State Water Survey.

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

SOIL REPORT NO. 7

McDONOUGH COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER,
J. H. PETTIT, and O. S. FISHER

URBANA, ILLINOIS, SEPTEMBER, 1913

INTRODUCTORY NOTE

About two-thirds of Illinois lies in the corn belt, where most of the prairie lands are black or dark brown in color. In the southern third of the state, the prairie soils are largely of a gray color. This region is better known as the wheat belt, altho wheat is often grown in the corn belt and corn is also a common crop in the wheat belt.

Moultrie county, representing the corn belt; Clay county, which is fairly representative of the wheat belt; and Hardin county, which is taken to represent the unglaciated area of the extreme southern part of the state, were selected for the first Illinois Soil Reports by counties. While these three county soil reports were sent to the Station's entire mailing list within the state, subsequent reports are sent only to the residents of the county concerned, and to any one else upon request.

Each county report is intended to be as nearly complete in itself as it is practicable to make it, and, even at the expense of some repetition, each will contain a general discussion of important fundamental principles in order to help the farmer and landowner understand the meaning of the soil fertility invoice for the lands in which he is interested. In Soil Report No. 1, "Clay County Soils," this discussion serves in part as an introduction, while in this and other reports, it will be found in the Appendix; but if necessary it should be read and studied in advance of the report proper.

McDONOUGH COUNTY SOILS

BY CYRIL G. HOPKINS, J. G. MOSIER, J. H. PETTIT, AND O. S. FISHER

McDonough county is located in the upper Illinois glaciation about midway between the Illinois and Mississippi rivers. It is divided into two rather distinct topographic areas: the southwestern, consisting largely of rolling or broken land, with good drainage; and the northern and eastern, of gently undulating topography and containing several areas originally very poorly drained. The rolling or hilly land comprizes 25 percent of the entire area of the county.

The difference in topography is due mainly to stream erosion, but it is very probable that an ice sheet which once covered the county did a great deal toward producing the present topography, especially in the region where erosion has played only a small part. The time when this county and much of the state was covered with this ice sheet is known as the Glacial period. During that period accumulations of snow and ice in parts of Canada became so great that they pushed southward until a point was reached where the ice melted as rapidly as it advanced. In moving across the country, the ice gathered up all sorts and sizes of stone and earth materials, including masses of rock, boulders, pebbles, and smaller particles. Some of these materials were carried for hundreds of miles and rubbed against the surface rocks or against each other until ground into powder. When the limit of advance was reached, where the ice largely melted, this material would accumulate in a broad undulating ridge or moraine. When the ice melted away more rapidly than the glacier advanced, the terminus of the glacier would recede and leave the moraine of glacial drift to mark the outer limit of the ice sheet.

The ice made many advances and with each advance and recession a terminal moraine was formed. These moraines are now seen as broad ridges that vary from one to ten miles in width. McDonough county possesses no distinct morainal ridge. Thruout the state, however, these advances and recessions of the ice sheet left a system of terminal moraines (irregularly concentric with Lake Michigan) having generally a steep outer slope while the inner slope is longer and more gradual. (See state map in Bulletin 123.)

The material transported by the glacier varied with the character of the rocks over which it passed. Granites, limestones, sandstones, shales, etc., were mixed and ground up together. This mixture of all kinds of boulders, gravel, sand, silt, and clay is called boulder clay, till, glacial drift, or simply drift. The grinding and denuding power of glaciers is enormous. A mass of ice 100 feet thick exerts a pressure of 40 pounds per square inch, and this ice sheet may have been thousands of feet in thickness. The materials carried and pushed along in this mass of ice, especially the boulders and pebbles, became powerful agents for grinding and wearing away the surface over which the ice passed. Ridges and hills were rubbed down, valleys filled, and surface features changed entirely.

As the glacier melted in its final recession, the material carried in the great mass of ice was deposited somewhat uniformly, yet not entirely so, over the intermorainal tracts, leaving extensive areas of level, undulating, or rolling plains. Practically the whole of McDonough county is covered with a deposit of this glacial drift, or boulder clay, to a depth varying from 10 to 140 feet and averaging approximately 50 to 60 feet. An illustration of an old filled valley is found in Macomb. According to Leverett, a deep well in the city penetrates 145 feet of drift, while other wells in the vicinity, at the same altitude, show only 60 feet of drift. This indicates a buried valley that was at least 85 feet deep. The surface left by the glacier in this county was slightly rolling, but not sufficiently so for complete drainage.

PHYSIOGRAPHY

McDonough county lies entirely in the drainage basin of the Illinois river. The highest part of the county is the northwest, where an altitude of 775 feet above sea level is reached. The lowest part is in the bottom land of Crooked creek at the south side of the county, which lies at an altitude of 500 feet. The average altitude is approximately 690 feet. Following are the altitudes of some of the railroad stations: Adair, 645; Bardolph, 671; Blandinsville, 730; Bushnell, 658; Colchester, 694; Good Hope, 714; Macomb, 700; New Philadelphia, 673; Prairie City, 659; Sciota, 754; Tennessee, 686.

At least 90 percent of McDonough county is drained thru Crooked creek; the other 10 percent is drained eastward into Spoon river. The larger streams of the county have cut valleys from 50 to 200 feet below the general upland. This has permitted the small tributaries to do considerable erosion, and as a result the upland adjacent to these larger streams is largely cut up into hills and valleys unsuited for ordinary agriculture.

SOIL MATERIAL AND SOIL TYPES

The Illinois glacier covered McDonough county and left a thick mantle of drift, completely burying the old soil that preceded it. Then a long period elapsed during which a deep soil, known as the old Sangamon soil, was formed on the Illinois drift. Later, other ice invasions of Illinois occurred, but they covered only the northern part of the state. (See state map in Bulletin 123, Iowan and Wisconsin glaciations.)

These later ice sheets did not reach McDonough county, but finely ground rock (rock flour) in immense quantities was carried south by the waters from the melting ice and deposited on the flooded plains of streams where it was picked up by the wind, carried out of these bottom lands and finally deposited on the upland, burying the drift material deposited by the Illinois glacier and the old Sangamon soil[1] to a depth of 5 to 20 feet or more. This wind-blown material, called loess, represents a mixture of all kinds of material over which the glacier passed.

After the loessal material was deposited over the country, the surface stratum became mixed with more or less organic matter and thus was gradually changed into soil. Surface washing has produced other changes.

[1]The Sangamon soil may sometimes be seen in cuts as a somewhat dark or bluish sticky clay or a weathered zone of yellowish or brownish clay.

The soils of McDonough county are divided into the three following classes:

(1) Upland prairie soils, rich in organic matter. These were originally covered with wild prairie grasses, the partially decayed roots of which have been the source of the organic matter. The flat, naturally poorly drained prairie land contains the higher amount of organic matter because the grasses and roots grew more luxuriantly there and were largely preserved from decay by the higher moisture content of the soil.

(2) Upland timber soils, including those zones along stream courses over which the forests once extended. These soils contain much less organic matter than the upland prairie soils because the large roots of dead trees and the surface accumulations of leaves, twigs, and fallen trees were burned by forest fires or suffered almost complete decay. The timber lands are divided chiefly into two classes—the undulating and the hilly areas.

(3) Swamp and bottom-land soils, which include the flood plains along streams.

Table 1 shows the area of each type of soil in McDonough county and its percentage of the total area. It will be noted that the common prairie soil (the brown silt loam) occupies 55 percent of the area of the county, while the yellow silt loam of the hilly land is the next most extensive type, covering 25 percent of the county.

Table 1.—Soil Types of McDonough County

Soil type No.	Name of type	Area in square miles	Area in acres	Percent of total area
	(a) Upland Prairie Soils (page 22)			
526	Brown silt loam	318.18	203 637	55.44
520	Black clay loam	19.22	12 301	3.35
528	Brown-gray silt loam on tight clay	29.25	18 720	5.10
525.1	Black silt loam on clay	7.24	4 634	1.26
	(b) Upland Timber Soils (page 27)			
535	Yellow silt loam	144.41	92 422	25.16
534	Yellow-gray silt loam	39.00	24 960	6.79
532	Light gray silt loam on tight clay	2.53	1 619	.44
	(c) Swamp and Bottom-Land Soils (page 34)			
1326	Deep brown silt loam	14.02	8 973	2.44
	(d) Miscellaneous			
	Lake	.10	64	.02
	Total	573.95	367 330	100.00

The accompanying maps show the location and boundary lines of every type of soil in the county, even down to areas of a few acres; and in Table 2 are reported the amounts of organic carbon (the best measure of the organic matter) and the total amounts of the five important elements of plant food contained in 2 million pounds of the surface soil of each type (the plowed soil of an acre about 6⅔ inches deep). In addition, the table shows the amount of limestone present, if any, or the amount of limestone required to neutralize the acidity existing in the soil.[1]

[1]The figures given in Table 2 (and in the corresponding tables for subsurface and subsoil) are the averages for all determinations, with some exceptions of limestone present or required. Some soil types, particularly those which are subject to erosion, may vary from acid to alkaline, especially in the subsurface or subsoil; and in such cases abnormal results are discarded, a report of the normal conditions being more useful than any average of figures involving both plus and minus quantities.

THE INVOICE AND INCREASE OF FERTILITY IN McDONOUGH COUNTY SOILS

SOIL ANALYSIS

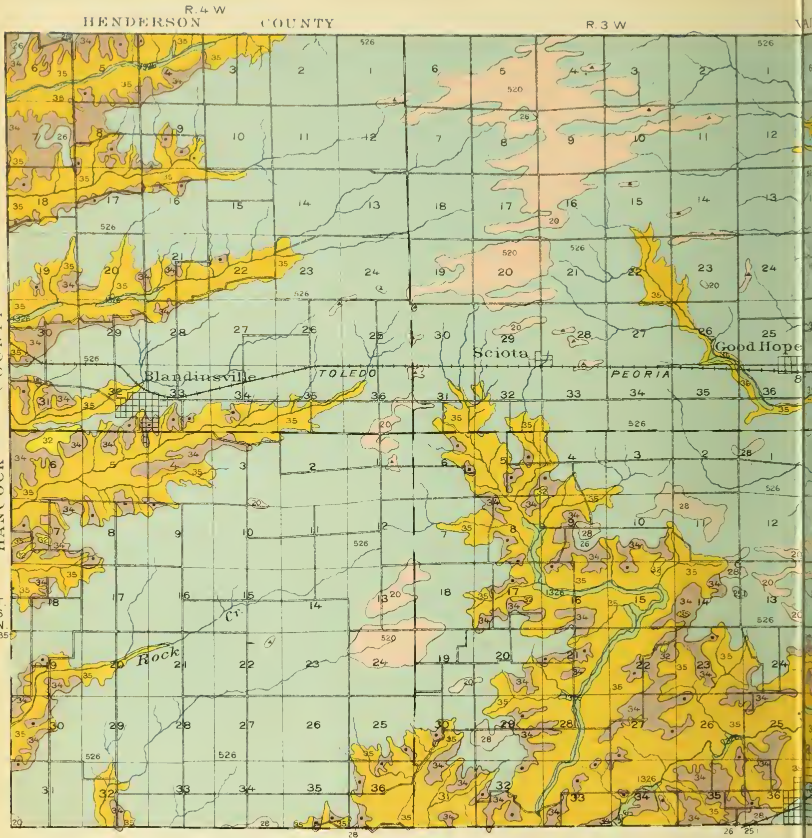
In order to avoid confusion in applying in a practical way the technical information contained in this report, the results are given in the most simplified form. The composition reported for a given soil type is, as a rule, the average of many analyses, which, like most things in nature, show more or less variation; but for all practical purposes the average is most trustworthy and sufficient. (See Bulletin 123, which reports the general soil survey of the state, together with many hundreds individual analyses of soil samples representing twenty-five of the most important and most extensive soil types in the state.)

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but, as explained in the Appendix, the rate of liberation is governed by many factors. Also, as there stated, probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that the productive power of normal soil in humid sections depends upon the stock of plant food contained in the soil and upon the rate at which it is liberated.

The fact may be repeated, too, that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all plants, only one (hydrogen) from water, while seven are secured from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes) in case the amount liberated from the soil is insufficient. But even the leguminous plants (which include the clovers, peas, beans, alfalfa, and vetches), in common with other agricultural plants, secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron, and sulfur) and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Table A in the Appendix shows the requirements of large crops for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally from natural sources in sufficient abundance, compared with the amounts needed by plants, so that they are never known to limit the yield of common farm crops.)

As already stated, the data in Table 2 represent the total amounts of plant-food elements found in 2 million pounds of surface soil, which corresponds to an acre about 6⅔ inches deep. This includes at least as much soil as is ordinarily turned with the plow, and represents that part with which the farm manure, limestone, phosphate, or other fertilizer applied in soil improvement is incorporated. It is the soil stratum that must be depended upon



LEGEND

UPLAND PRAIRIE SOILS

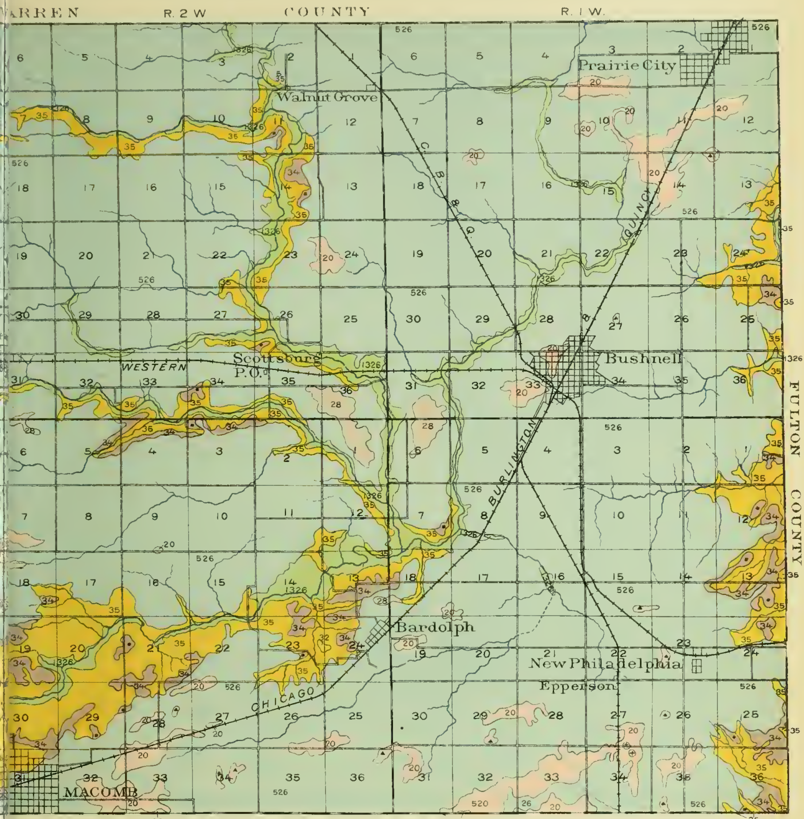
26 526	Brown silt loam
20 520	Black clay loam
28 528	Brown-gray silt loam on tight clay
25.1 525.1	Black silt loam on clay.

UPLAND TIMBER SOILS

34 534	Yellow-gray silt loam
35 535	Yellow silt loam
32 532	Light gray silt loam on tight clay

SOIL SURVEY MAP OF

UNIVERSITY OF ILLINOIS AGRIC



'AMP AND BOTTOM
LAND SOILS

1326	Deep brown silt loam

Scale
0 ¼ ½ 1 2 Miles

ICDONOUGH COUNTY
LTURAL EXPERIMENT STATION

Table 2.—Fertility in the Soils of McDonough County

Average pounds per acre in 2 million pounds of surface soil (about 0 to 6⅔ inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone requir'd
	Upland Prairie Soils								
526	Brown silt loam	49 810	4 260	1 098	33 090	9 794	11 460		70
520	Black clay loam	78 470	6 167	1 587	29 640	13 667	19 673		30
528	Brown-gray silt loam on tight clay..	39 800	3 400	900	31 740	6 400	8 200		100
525.1	Black silt loam on clay.	64 180	5 420	940	30 960	10 440	15 460		60
	Upland Timber Soils								
534	Yellow-gray silt loam..........	27 070	2 620	880	36 870	6 270	8 105		70
535	Yellow silt loam	21 460	2 140	830	37 530	6 490	7 060		60
532	Light gray silt loam on tight clay.....	16 080	1 460	920	35 140	6 420	6 680		140
	Swamp and Bottom-Land Soils								
1326	Deep brown silt loam	47 140	4 580	1 740	37 360	9 140	10 960		40

in large part to furnish the necessary plant food for the production of crops, as will be seen from the information given in the Appendix. Even a rich subsoil has little or no value if it lies beneath a worn-out surface, for the weak, shallow-rooted plants will be unable to reach the supply of plant food in the subsoil. If, however, the fertility of the surface soil is maintained at a high point, then the plants, with a vigorous start from the rich surface soil, can draw upon the subsurface and subsoil for a greater supply of plant food.

By easy computation it will be found that the most common prairie soil of McDonough county does not contain more than enough total nitrogen in the plowed soil for the production of maximum crops for nine rotations (36 years); while the upland timber soils contain, as an average, only one-half as much nitrogen as the prairie land.

With respect to phosphorus, the condition differs only in degree, nine-tenths of the soil area of the county containing no more of that element than would be required for fifteen crop rotations if such yields were secured as are suggested in Table A of the Appendix. It will be seen from the same table that in the case of the cereals about three-fourths of the phosphorus taken from the soil is deposited in the grain, while only one-fourth remains in the straw or stalks.

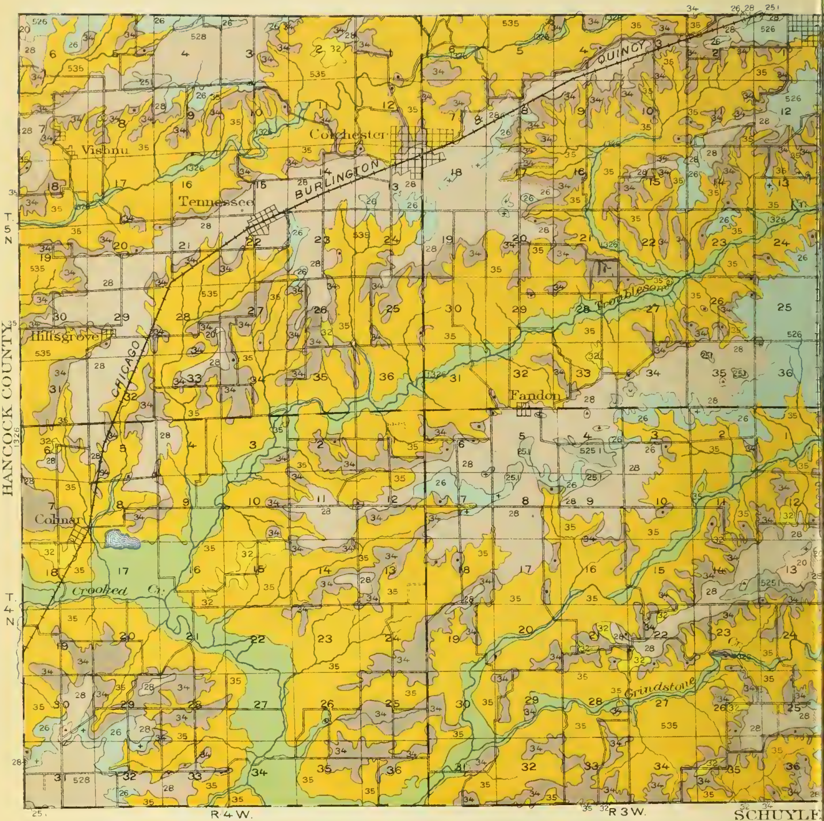
On the other hand, the potassium is sufficient for 25 centuries if only the grain is sold, or for 400 years even if the total crops should be removed and nothing returned. The corresponding figures are about 2500 and 600 years for magnesium, and about 15,000 and 300 years for calcium. Thus, when measured by the actual crop requirements for plant food, potassium is no more limited than magnesium and calcium, and, as explained in the Appen-

PLATE 1.—WHEAT IN 1911 ON URBANA FIELD
COVER CROPS AND CROP RESIDUES PLOWED UNDER
AVERAGE YIELD, 35.2 BUSHELS PER ACRE

dix, with these elements we must also consider the fact that loss by leaching is far greater than by cropping.

These general statements relating to the total quantities of plant food in the plowed soil certainly emphasize the fact that the supplies of some of these necessary elements of fertility are extremely limited when measured by the needs of large crop yields for even one or two generations of people.

The variation among the different types of soil in McDonough county with respect to their content of important plant-food elements is also very marked. Thus, the richest prairie land, the black clay loam, contains about twice as much phosphorus and two to three times as much nitrogen as the common upland timber soils. On the other hand, the most significant fact revealed by the investigation of the soils of this county is the low phosphorus content of the common brown silt loam prairie, a type of soil that covers more than half the entire county. The market value of this land is about $200 an acre, and yet an application of forty dollars' worth of fine-ground



LEGEND

UPLAND PRAIRIE SOILS

26 / 526 Brown silt loam

20 / 520 Black clay loam

28 / 528 Brown-gray silt loam on tight clay

25.1 / 525.1 Black silt loam on clay.

UPLAND TIMBER SOILS

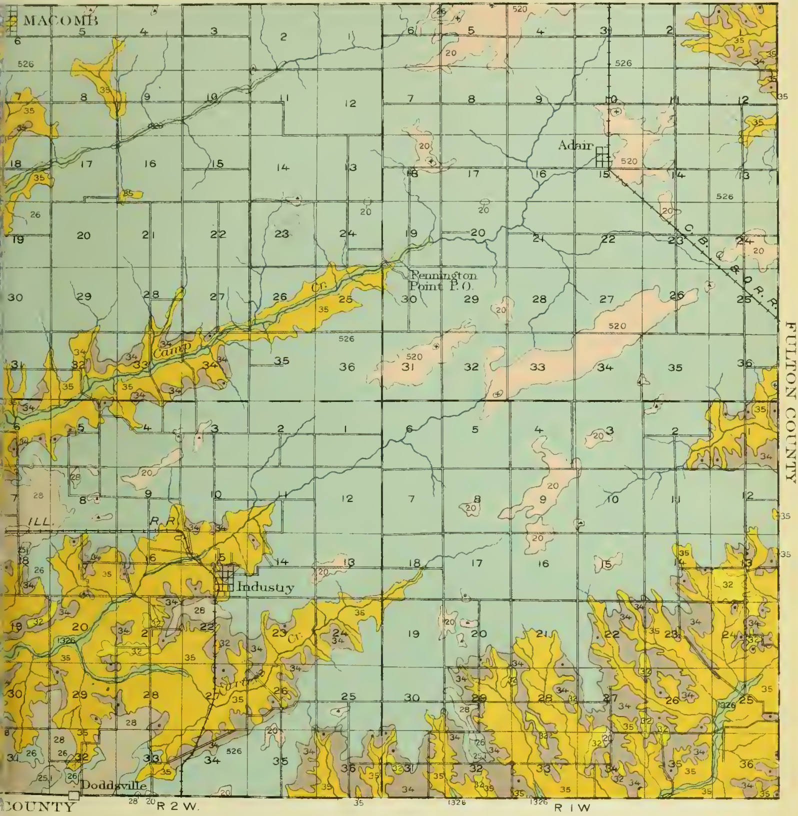
34 / 534 Yellow-gray silt loam

35 / 535 Yellow silt loam

32 / 532 Light gray silt loam on tight cl

SOIL SURVEY MAP OF

UNIVERSITY OF ILLINOIS AGRIC



SWAMP AND BOTTOM
LAND SOILS

1326 Deep brown silt loam

Scale
0 ¼ ½ 1 2 Miles

CDONOUGH COUNTY
TURAL EXPERIMENT STATION

Plate 2.—Wheat in 1911 on Urbana Field
Cover Crops and Crop Residues Plowed Under
Fine-Ground Rock Phosphate Applied
Average Yield, 50.1 Bushels Per Acre

raw rock phosphate would double the phosphorus content of the plowed soil, and, if properly made, would in the near future double the yield of clover. If the clover were then returned to the soil, either directly or in farm manure, the combined effect of phosphorus and increased nitrogenous organic matter, with a good rotation of crops, would in time double the yield of corn on most farms. The same treatment would produce equally good results on the undulating upland timber soils.

With more than 4000 pounds of nitrogen in the prairie soil and an inexhaustible supply in the air, with 33,000 pounds of potassium in the same soil, and with practically no acidity, the economic loss in farming such land with only 1100 pounds of total phosphorus in the plowed soil can be appreciated only by the man who fully realizes that in less than one generation the crop yields could be doubled by adding phosphorus,—without change of seed or season and with very little more work than is now devoted to the

Plate 3.—Wheat in 1911 on Urbana Field
Cover Crops and Farm Manure Plowed Under
Average Yield, 34.2 Bushels Per Acre

fields. Fortunately, some definite field experiments have already been conducted on this most extensive type of soil, both in the upper Illinois glaciation in Knox county and on similar soil in the early Wisconsin glaciation, as at Urbana in Champaign county, at Sibley in Ford county, and at Bloomington in McLean county.

Results of Field Experiments at Urbana

A three-year rotation of corn, oats, and clover was begun on the North Farm at the University of Illinois in 1902, on three fields of typical brown silt loam prairie land which, after twenty years or more of pasturing, had grown corn in 1895, 1896, and 1897 (when careful records were kept of the yields produced) and had then been cropped with clover and grass on one field, oats on another, and oats, cowpeas, and corn on the third field, until 1901. As an average of the first three years (1902-1904) phosphorus

Plate 4.—Wheat in 1911 on Urbana Field
Cover Crops and Farm Manure Plowed Under
Fine-Ground Rock Phosphate Applied
Average Yield, 51.8 Bushels Per Acre

increased the crop yields per acre by .68 ton of clover, 8.8 bushels of corn, and 1.9 bushels of oats. During the second three years (1905-1907) it produced average increases of .79 ton of clover, 13.2 bushels of corn, and 11.9 bushels of oats. During the third course of the rotation (1908-1910) it produced average increases of 1.05 tons of clover, 18.7 bushels of corn, and 8.4 bushels of oats. For convenient reference the results are summarized in Table 3.

Wheat is grown on the University South Farm in a rotation experiment started more recently. As an average of the four years 1908 to 1911, raw rock phosphate (with no previous application of bone meal) increased the yield of wheat by 10.3 bushels per acre. Here, too, as an average of the four years, the phosphorus applied paid back about twice its cost. In the grain system of farming, the yield of wheat in 1911 was 35.2 bushels per

acre where cover crops and crop residues are plowed under without the use of phosphorus; but where rock phosphate is used the average yield was 50.1 bushels (see Plates 1 and 2). In the live-stock system, the yield of wheat in 1911 was 34.2 bushels where manure and cover crops are used without phosphate; and 51.8 bushels, as an average, where rock phosphate is used in addition (see Plates 3 and 4). These results emphasize the cumulative effect of permanent systems of soil improvement.

TABLE 3.—EFFECT OF PHOSPHORUS ON BROWN SILT LOAM AT URBANA
(Average increase per acre)

Rotation	Years	Corn, bu.	Oats, bu.	Clover, tons	Value of increase[1]	Cost of treatment[1]
First..........	1902,-3,-4	8.8	1.9	.68	$ 7.73	$7.50
Second	1905,-6,-7	13.2	11.9	.79	12.93	7.50
Third.........	1908,-9,-10	18.7	8.4	1.05	15.37	7.17

[1]Prices used are 35 cents a bushel for corn, 30 cents for oats, $6 a ton for clover hay, 10 and 3 cents a pound, respectively, for phosphorus in bone meal and in rock phosphate. (Only steamed bone meal was used from 1902 to 1907, but subsequently three times as much rock phosphate has been used, at less cost, on one half of each phosphorus plot.)

Wheat has also been grown on the North Farm during the last three years (1911, '12, '13), and the average increase produced by phosphorus (part in bone meal and part in raw phosphate) has been 12.4 bushels per acre per year.

RESULTS OF EXPERIMENTS ON SIBLEY FIELD

Table 4 gives the results obtained during the past eleven years from the Sibley soil experiment field located in Ford county on the typical brown silt loam prairie of the Illinois corn belt.

Previous to 1902 this land had been cropped with corn and oats for many years under a system of tenant farming, and the soil had become somewhat deficient in active organic matter. While phosphorus was the limiting element of plant food, the supply of nitrogen becoming available annually was but little in excess of the phosphorus, as is well shown by the corn yields for 1903, when the addition of phosphorus produced an increase of 8 bushels, nitrogen produced no increase, but nitrogen and phosphorus together increased the yield by 15 bushels.

After six years of additional cropping, however, nitrogen appeared to become the most limiting element, the increase in the corn in 1907 being 9 bushels from nitrogen and only 5 bushels from phosphorus, while both together produced an increase of 33 bushels. By comparing the corn yields for the four years 1902, 1903, 1906, and 1907, it will be seen that the untreated land has apparently grown less productive, whereas, on land receiving both phosphorus and nitrogen the yield has appreciably increased, so that in 1907, when the untreated rotated land produced only 34 bushels of corn per acre, a yield of 72 bushels (more than twice as much) was produced where lime, nitrogen, and phosphorus had been applied, altho the two plots produced exactly the same yield (57.3 bushels) in 1902.

Even in the unfavorable season of 1910, the yield of the highest producing plot exceeded the yield of the same plot in 1902, while the untreated land produced less than half as much as it produced in 1902. The prolonged drouth of 1911 resulted in almost a failure of the corn crop, but nevertheless

TABLE 4.—CROP YIELDS IN SOIL EXPERIMENTS, SIBLEY FIELD

Brown silt loam prairie; early Wisconsin glaciation		Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912
Plot	Soil treatment applied	Bushels per acre										
101	None	57.3	50.4	74.4	29.5	36.7	33.9	25.9	25.3	26.6	20.7	84.4
102	Lime	60.0	54.0	74.7	31.7	39.2	38.9	24.7	28.8	34.0	22.2	85.6
103	Lime, nitrogen	60.0	54.3	77.5	32.8	41.7	48.1	36.3	19.0	29.0	22.4	25.3
104	Lime, phosphorus	61.3	62.3	92.5	36.3	44.8	43.5	25.6	32.2	52.0	31.6	92.3
105	Lime, potassium	56.0	49.9	74.4	30.2	37.5	34.9	22.2	23.2	34.2	21.6	83.1
106	Lime, nitrogen, phosphorus	57.3	69.1	88.4	45.2	68.5	72.3	45.6	33.3	55.6	35.3	42.2
107	Lime, nitrogen, potassium	53.3	51.4	75.9	37.7	39.7	51.1	42.2	25.8	46.2	20.1	55.6
108	Lime, phosphorus, potassium	58.7	60.9	80.0	39.8	41.5	39.8	27.2	28.5	43.0	31.8	79.7
109	Lime, nitrogen, phos., potas.	58.7	65.9	82.5	48.0	69.5	80.1	52.8	35.0	58.0	35.7	57.2
110	Nitro., phos., potassium	60.0	60.1	85.0	48.5	63.3	72.3	44.1	30.8	64.4	31.5	54.1
Average Increase: Bushels per Acre												
For nitrogen		−1.7	3.4	.7	6.4	14.1	23.6	19.3	.1	6.4	1.6	−40.1
For phosphorus		1.7	12.1	10.7	9.2	16.5	15.7	6.4	8.1	16.3	12.0	5.4
For potassium		−3.0	−2.9	−5.1	2.4	−1.5	1.0	3.0	− .2	2.7	− .6	7.5
For nitro., phos., over phos.		−4.0	6.8	−4.1	8.9	23.7	28.8	20.0	1.1	3.6	3.7	−50.1
For phos., nitro. over nitro		−2.7	14.8	10.9	12.4	26.8	24.2	9.3	14.3	26.6	12.9	16.9
For potas., nitro., phos. over nitro., phos.		1.4	−3.2	−5.9	2.8	1.0	7.8	7.2	1.7	2.4	.4	15.0

Value of Crops per Acre in Eleven Years

Plot	Soil treatment applied	Total value of eleven crops	Value of increase
101	None	$ 172.73	
102	Lime	184.75	$ 12.02
103	Lime, nitrogen	167.42	— 5.31
104	Lime, phosphorus	214.50	41.77
105	Lime, potassium	173.22	.49
106	Lime, nitrogen, phosphorus	233.15	60.42
107	Lime, nitrogen, potassium	188.19	15.46
108	Lime, phosphorus, potassium	200.37	27.64
109	Lime, nitrogen, phosphorus, potassium	244.62	71.89
110	Nitrogen, phosphorus, potassium	233.54	60.81

Value of Increase per Acre in Eleven Years		Cost of increase
For nitrogen	$−17.33	$ 165.00
For phosphorus	29.75	27.50
For *nitrogen* and phosphorus over phosphorus	18.65	165.00
For *phosphorus* and nitrogen over nitrogen	65.73	27.50
For *potassium*, nitrogen, and phosphorus over nitrogen and phosphorus	11.47	27.50

the effect of soil treatment was seen. Phosphorus appeared to be the first limiting element again in 1909, 1910, and 1911; while the lodging of oats, especially on the nitrogen plots, in the exceptionally favorable season of 1912, produced very irregular results.

In the lower part of Table 4 are shown the total values per acre of the eleven crops from each of the ten different plots, the amounts varying from $167.42 to $244.62; also the value of the increase produced in crop yields above the value of the yields from the untreated land, corn being valued at 35 cents a bushel, oats at 30 cents, and wheat at 70 cents. Phosphorus without nitrogen has produced $29.75 in addition to the increase by lime; but with nitrogen it has produced $65.73 above the crop values where only lime and nitrogen have been used. The results show that in 25 cases out of 44 the addition of potassium has decreased the crop yields. Even under the most favorable conditions, and with no effort to liberate potassium from the soil by adding organic matter, potassium has paid back less than half its cost.

By comparing Plots 101 and 102, and also 109 and 110, it will be seen that lime has produced an average increase of $11.55, or more than $1 an acre a year. Altho this increase may have been above normal on these plots because of the condition of the soil at the beginning of the experiment, it suggests that the time is here when limestone must be applied to some of these brown silt loam soils.

While nitrogen, on the whole, has produced an appreciable increase, especially on those plots to which phosphorus has also been added, it has cost, in commercial form, so much above the value of the increase produced that the only conclusion to be drawn, if we are to utilize this fact to advantage, is that the nitrogen must be secured from the air.

RESULTS OF EXPERIMENTS ON BLOOMINGTON FIELD

Space is taken to insert Table 5, giving all the results thus far obtained from the Bloomington soil experiment field, which is also located on the brown silt loam prairie soil of the Illinois corn belt.

The general results of the eleven years' work on the Bloomington field tell much the same story as those from the Sibley field. The rotations have differed since 1905 by the use of clover and the discontinuing of the use of commercial nitrogen on the Bloomington field; in consequence of which phosphorus without commercial nitrogen, on the Bloomington field, has produced an even larger increase ($89.92) than has been produced by phosphorus and nitrogen over nitrogen on the Sibley field ($65.73).

It should be stated that a draw runs near Plot 110 on the Bloomington field, that the crops on that plot are sometimes damaged by overflow or imperfect drainage, and that Plot 101 occupies the lowest ground on the opposite side of the field. In part because of these irregularities and in part because only one small application has been made, no conclusions can be drawn in regard to lime. Otherwise all results reported in Table 5 are considered reliable. They not only furnish much information in themselves, but they also offer instructive comparison with the Sibley field.

Wherever nitrogen has been provided, either by direct application or by the use of legume crops, the addition of the element phosphorus has produced very marked increases, the average yearly increase for the Bloomington field being worth $7.11 an acre. This is $4.61 above the cost of the phosphorus

TABLE 5.—CROP YIELDS IN SOIL EXPERIMENTS, BLOOMINGTON FIELD

Brown silt loam prairie; early Wisconsin glaciation		Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Corn 1908	Oats 1909	Clover[2] 1910	Wheat 1911	Corn 1912
Plot	Soil treatment applied	Bushels or tons per acre										
101	None	30.8	63.9	54.8	30 8	.39	60.8	40.3	46.4	1.56	22.5	55.2
102	Lime	37.0	60.3	60.8	28.8	.58	63.1	35.3	53 6	1.09	22.5	47.9
103	Lime, crop res.[1]	35.1	59.5	69.8	30.5	.46	64.3	36.9	49.4	(.83)	25.6	62.5
104	Lime, phosphorus	41.7	73.0	72.7	39.2	1.65	82.1	47.5	63.8	4.21	57.6	74.5
105	Lime, potassium	37.7	56.4	62.5	33.2	.51	64.1	36.2	45.3	1.26	21.7	57.8
106	Lime, residues,[1] phosphorus	43.9	77.6	85.3	50.9	[3]	78.9	45.8	72.5	(1.67)	60.2	86.1
107	Lime, residues,[1] potassium	40.4	58.9	66.4	29.5	.81	64.3	31.0	51.1	(.33)	27.3	58.9
108	Lime, phosphorus, potassium	50.1	74.8	70.3	37.8	2.36	81.4	57.2	59.5	3.27	54.0	73.2
109	Lime, res.,[1] phos., potassium	52.7	80.9	90.5	51.9	[3]	88.4	58.1	64.2	(.42)	60.4	83.4
110	Res., phosphorus, potassium	52.3	73.1	71.4	51.1	[3]	78.0	51.4	55.3	(.60)	61.0	78.3

Average Increase: Bushels or Tons per Acre

	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Corn 1908	Oats 1909	Clover 1910	Wheat 1911	Corn 1912
For residues	1.4	3.1	11.4	5.9	−.96	1.3	−1.1	3.7	−1.64	4.4	7.9
For phosphorus	9.5	17.8	14.8	14.4	.41	18.8	18.0	15.1	1.51	33.9	24.0
For potassium	5.8	.2	.3	.7	.25	2.4	4.2	−4.8	−.63	−.6	2.1
For res., phos. over phos.	2.2	4.6	12.6	11.7	−1.65	−3.2	−1.7	8.7	−2.25	2.6	11.6
For phos., res. over res.	8.8	18.1	15.5	20.4	−.46	14.6	8.9	23.1	.84	34.6	23.6
For potas., res., phos. over res., phos.	8.8	3.3	5.2	1.0	.00	9.5	12.3	−8.3	−1.25	.2	−2.7

Value of Crops per Acre in Eleven Years

Plot	Soil treatment applied	Total value of eleven crops	Value of increase
101	None	$167.22	
102	Lime	165.52	—$1.70
103	Lime, residues	173.17	5.95
104	Lime, phosphorus	255.44	88.22
105	Lime, potassium	169.66	2.44
106	Lime, residues, phosphorus	251.43	84.21
107	Lime, residues, potassium	170.57	3.36
108	Lime, phosphorus, potassium	256.92	89.70
109	Lime, residues, phosphorus, potassium	254.76	87.54
110	Residues, phosphorus, potassium	236.66	69.44

Value of Increase per Acre in Eleven Years		Cost of increase
For residues	$ 7.65	?
For phosphorus	89.92	$27.50
For *residues* and phosphorus over phosphorus	—4.01	?
For *phosphorus* and residues over residues	78.26	27.50
For *potassium*, residues, and phosphorus over residues and phosphorus	3.33	27.50

[1]Commercial nitrogen was used 1902–1905.
[2]The figures in parentheses mean bushels of seed; the others, tons of hay.
[3]Clover smothered by previous wheat crop.

in 200 pounds of steamed bone meal, the form in which it is applied to the Sibley and the Bloomington fields. On the other hand, the use of phosphorus without nitrogen will not maintain the fertility of the soil (see Plots 104 and 106, Sibley field). As the only practical and profitable method of supplying nitrogen, a liberal use of clover or other legumes is suggested, the legume to be plowed under either directly or as manure, preferably in connection with the phosphorus applied, especially if raw rock phosphate is used.

From the soil of the best treated plots on the Bloomington field, 160 pounds per acre of phosphorus, as an average, have been removed in the eleven crops. This is equal to more than 13 percent of the total phosphorus contained in the surface soil of an acre of the untreated land. In other words, if such crops could be grown for eighty years, they would require as much phosphorus as the total supply in the ordinary plowed soil. The results plainly show, however, that without the addition of phosphorus such crops cannot be grown year after year. Where no phosphorus has been applied, the crops have removed only 107 pounds of phosphorus in the eleven years, which is equivalent to only 9 percent of the total amount (1,200 pounds) that was present in the surface soil at the beginning of the experiment in 1902. The total phosphorus applied from 1902 to 1912, as an average of all plots where it has been used, has amounted to 275 pounds per acre and has cost $27.50. This has paid back $84.91, or 300 percent on the investment; whereas potassium, used in the same number of tests and at the same cost, has paid back only $1.59 per acre in the eleven years, or less than 6 percent of its cost. Are not these results to be expected from the composition of the soil and the requirements of crops? (See Table 2, page 5, and also Table A in the Appendix.)

Nitrogen was applied to this field, in commercial form only, from 1902 to 1905; but clover was grown in 1906 and 1910, and a catch crop of cowpeas after the clover in 1906. The cowpeas were plowed under on all plots, and the 1910 clover (except the seed) was plowed under on five plots (103, 106, 107, 109, and 110). Straw and corn stalks have also been returned to these plots in recent years. The effect of returning these residues to the soil is already appreciable (an average increase of 4.4 bushels of wheat in 1911 and 7.9 bushels of corn in 1912) and probably will be more marked on subsequent crops. Indeed, the large crops of corn, oats, and wheat grown on Plots 104 and 108 during the eleven years have drawn their nitrogen very largely from the natural supply in the organic matter of the soil. The roots and stubble of clover contain no more nitrogen than the entire plant takes from the soil alone, but they decay rapidly in contact with the soil and probably hasten the decomposition of the soil humus and the consequent liberation of the soil nitrogen. But of course there is a limit to the reserve stock of humus and nitrogen remaining in the soil, and the future years will undoubtedly witness a gradually increasing difference between Plots 104 and 106, and between Plots 108 and 109, in the yields of grain crops.

Plate 5 shows graphically the relative values of the eleven crops for the eight comparable plots, Nos. 102 to 109. The cost of the phosphorus is indicated by that part of the diagram above the short crossbars. It should be kept in mind that no value is assigned to clover plowed under except as it reappears in the increase of subsequent crops. Plots 106 and 109 are heavily handicapped because of the clover failure on those plots in 1906 and the poor yield of clover seed in 1910, whereas Plots 104 and 108 produced a fair crop in 1906 and a very large crop in 1910. As an average, Plots 106 and 109 are only $3.09 behind Plots 104 and 108 in the value of the eleven crops

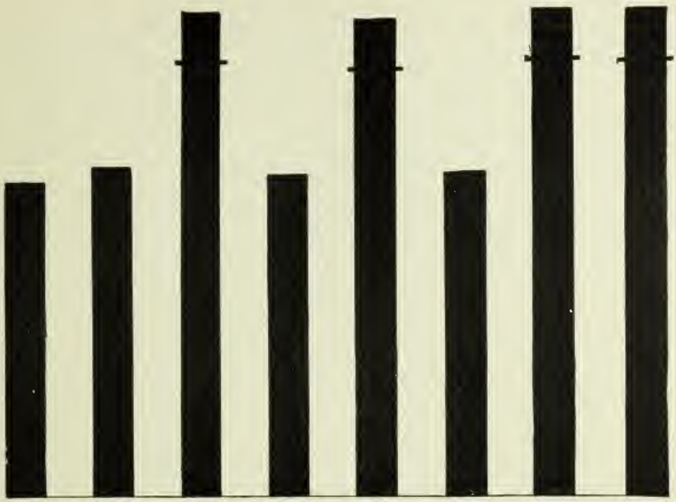


Plate 5.—Crop Values for Eleven Years
Bloomington Experiment Field

(R=residues; P=phosphorus; K=potassium, or kalium)

harvested, and this would have been covered by about ½ bushel more clover seed in 1906 or 1910, or it may be covered by 10 bushels more corn in 1913. The values from Plots 103 and 107 average $4.28 more than the values from Plots 102 and 105. (See also table on last page of cover.)

Results of Field Experiments at Galesburg

In Tables 6, 7, and 8 are reported in detail the results obtained from the University of Illinois soil experiment field near Galesburg, on the line between Knox and Warren counties, on the brown silt loam prairie soil of the upper Illinois glaciation.

A six-year rotation has been practiced on this field since 1904. During the first six years the order of cropping was corn, corn, oats, wheat, followed by two years of clover and timothy. Since then the rotation has been corn, corn, oats, clover, wheat, clover. There are only three independent series of plots, so that while corn is grown every year the other crops are harvested only in alternate years, altho clover should be on the field every year, either in the stubble of the oats and wheat or as a regular crop.

Each series contains twenty individual fifth-acre plots, 2 rods wide and 16 rods long, with half-rod division strips cultivated and cropped between the plots, a quarter-rod border cultivated and cropped surrounding each

TABLE 6.—CROP YIELDS IN SOIL EXPERIMENTS, GALESBURG FIELD: SERIES 100

Brown silt loam prairie; upper Illinois glaciation		Corn 1904	Corn 1905	Oats 1906	Wheat 1907	Clover[1] 1908	Timothy[1] 1909	Corn 1910	Corn 1911	Oats 1912
Plot	Soil treatment applied	Bushels or tons per acre								
101	Lime	63.8	52.5	53.8	34.0	2.71	2.04	59.8	66.5	53.3
102	Residues, lime	67.3	49.8	53.6	41.4	(.96)	(3.83)	72.6	75.1	56.9
103	Manure, lime	64.7	48.1	50.3	31.6	2.59	1.83	77.6	81.0	60.0
104	Cover crop, manure, lime	65.3	46.5	46.7	32.8	2.61	1.70	77.9	78.9	70.2
105	Lime	74.7	54.9	52.3	35.1	2.80	2.05	66.2	67.4	60.8
106	Lime, phosphorus	78.2	66.1	53.9	41.9	3.18	2.58	72.4	79.4	68.6
107	Residues, lime, phosphorus	75.9	63.1	55.0	41.3	(.67)	(4.92)	78.0	83.8	65.2
108	Manure, lime, phosphorus	72.6	61.1	54.2	37.9	3.18	2.36	74.6	79.8	77.3
109	Cover crop, manure, lime, phosphorus	74.1	60.0	54.2	40.0	3.15	2.33	74.0	79.1	74.4
110	Lime	72.4	58.8	50.5	32.7	2.65	1.74	61.5	59.2	54.5
111	Lime, phosphorus, potassium	81.2	72.3	53.9	36.6	3.21	2.42	74.5	81.1	70.9
112	Residues, lime, phosphorus, potassium	82.3	71.0	59.4	41.1	(.58)	(5.00)	81.9	83.7	59.5
113	Manure, lime, phosphorus, potassium	77.1	72.2	52.8	36.1	3.45	2.49	77.6	82.4	74.4
114	Cover crop, manure, lime, phos., potassium	89.4	69.9	54.5	38.7	3.36	2.55	75.9	85.0	70.0
115	Lime	81.2	68.1	62.8	36.8	2.99	2.19	59.4	67.3	53.0
116	Residues	77.1	61.8	57.3	38.2	(1.17)	(5.33)	70.6	68.9	52.0
117	Residues, phosphorus	79.4	64.2	60.0	36.2	(1.25)	(5.50)	75.0	77.5	66.1
118	Residues, phosphorus, potassium	82.3	70.8	52.0	40.9	(1.38)	(4.75)	78.3	78.4	68.1
119	Residues, lime, nitrogen, phos., potassium	87.1	76.3	66.2	46.0	(1.08)	(5.00)	74.8	79.3	67.3
120	None	82.9	65.1	65.3	45.8	3.04	2.82	72.7	67.4	70.2
Increase for residues						—2.19	—.89	5.9	4.3	—7.3
Increase for manure								7.7	5.4	6.3
Increase for phosphorus		6.2	10.7	3.4	3.6	.26	.42	1.8	5.7	10.3
Increase for potassium		6.4	8.3	—.9	—.8	.11	—.01	2.8	2.2	—1.7
Increase for nitrogen		4.8	5.5	14.2	5.1	—(.30)	(.25)	—3.5	.9	—.8

[1]The figures in parentheses in these columns represent bushels of seed; the others, tons of hay.

series, and grass strips about two rods wide between the series and surrounding the experiment field. The soil treatment for the individual plots is indicated in Tables 6, 7, and 8.

Limestone was applied in small amount (1300 pounds per acre) to the first fifteen plots in each series in 1904. No further application was made until the spring of 1912, when 4 tons per acre were applied to Plots 1 to 15 of Series 300. Thus far no apparent effect has been produced, but further experiment with liberal applications may show results. Plots 1 to 15 in Series 100 and 200 were given 4 tons per acre in the spring of 1913.

The "residues" include the straw and corn stalks, all clover except the seed, and legume cover crops, such as cowpeas, soybeans, or vetch, seeded in the corn at the last cultivation. These are returned to certain plots in order to supply nitrogen and organic matter in a system of grain farming. This system was not fully under way on all series until 1911, as may be seen from the lower parts of Tables 6, 7, and 8, so that as yet no conclusions regarding this treatment are justified, except that it provides an abundance of organic matter. Whether the value of the clover plowed under will ultimately reap-

TABLE 7.—CROP YIELDS IN SOIL EXPERIMENTS, GALESBURG FIELD: SERIES 200

Brown silt loam prairie; upper Illinois glaciation		Oats 1904	Wheat 1905	Clover 1906	Timothy 1907	Corn 1908	Corn 1909	Oats 1910	Clover 1911	Wheat 1912
Plot	Soil treatment applied	Bushels or tons per acre								
201	Lime	57.5	40.5	.72	2.30	79.8	54.1	48.0	1.39	17.5
202	Residues, lime	55.0	40.0	.63	1.31	78.8	51.9	43.3		21.1
203	Manure, lime	52.5	38.5	.57	2.55	101.3	65.6	50.6	2.64	21.7
204	Cover crop, manure, lime	55.0	40.2	.63	2.73	102.7	66.8	53.0	2.32	19.6
205	Lime	67.5	42.2	1.22	2.84	86.3	54.4	44.4	2.29	18.2
206	Lime, phosphorus	62.5	41.3	1.36	3.27	99.6	59.1	55.5	2.42	27.3
207	Residues, lime, phosphorus	57.5	42.2	.90	1.79	105.6	49.4	48.6		27.3
208	Manure, lime, phosphorus	60.0	40.0	.91	3.18	106.6	69.8	58.6	2.30	27.3
209	Cover crop, manure, lime, phos.	50.0	39.0	.91	3.16	105.8	75.7	60.3	2.03	27.8
210	Lime	57.5	37.5	.69	2.46	84.5	57.8	42.3	1.14	12.2
211	Lime, phosphorus, potassium	55.0	38.7	1.31	3.38	95.7	67.0	55.3	2.01	28.2
212	Residues, lime, phosphorus, potassium	65.0	39.3	1.40	2.15	103.3	57.5	53.8		28.3
213	Manure, lime, phosphorus, potassium	65.0	41.5	1.79	3.62	98.1	69.8	58.3	2.55	25.9
214	Cover crop, manure, lime, phos., potas.	62.5	40.7	1.51	3.48	102.8	73.3	62.8	2.46	25.3
215	Lime	60.0	35.5	.83	2.33	84.1	58.2	41.6	.98	8.8
216	Residues	72.5	37.0	.82	1.37	87.3	54.8	38.6		11.8
217	Residues, phosphorus	57.5	38.7	.85	1.44	98.6	49.6	43.4		22.1
218	Residues, phosphorus, potassium	50.0	40.7	1.51	2.17	99.0	43.0	46.3		28.3
219	Residues, lime, nitrogen, phos., potas.	57.5	37.7	1.21	1.98	109.6	47.2	57.2		27.3
220	None	55.0	39.5	.71	2.49	88.3	49.5	38.1	1.00	15.6
Increase for residues								—3.1	—1.70	0.0
Increase for manure						7.7	8.3	2.9	.56	.6
Increase for phosphorus		—3.0	.7	.21	.41	12.0	2.0	7.3	—.17	7.7
Increase for potassium		2.0	— .1	.52	.39	—3.5	1.4	2.0	.09	.8
Increase for nitrogen		7.5	—3.0	—.30	—.19	10.6	4.2	10.9		—1.0

pear in subsequent yields of grain and seed, must be determined by the further accumulation of data.[1]

Farm manure is applied to certain plots (see tables) in proportion to their previous average crop yields; that is, as many tons of manure are applied to each plot as there were average tons of air-dry produce removed from the corresponding plots during the previous rotation, but no manure

[1]Alsike, mammoth, and sweet clover promise to yield the better returns in seed, altho in some cases seed has been threshed from both the first and second cuttings of the red clover. It is quite possible that better average results would be secured by regularly removing the first cutting of red clover. with the purpose of threshing it for seed, as well as the second cutting if found advisable. Some splendid seed crops have been secured from the second cutting when the first was clipped and left on the land, but under other seasonal conditions the second crop has been a failure. In such cases, altho the apparent effect is a total loss of the clover crop, at least part of this apparent loss is recovered in subsequent crops of grain. It should never be forgotten that the purpose of this system is to enable the grain farmer to maintain the fertility of his soil, even tho some other system which he may not be prepared to adopt might be more profitable.

TABLE 8.—CROP YIELDS IN SOIL EXPERIMENTS, GALESBURG FIELD: SERIES 300

Brown silt loam prairie; upper Illinois glaciation		Timothy 1904	Timothy 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Wheat 1910	Clover 1911	Corn 1912
Plot	Soil treatment applied	Bushels or tons per acre								
301	Lime	1.36	1.54	66.8	75.9	28.6	31.7	16.2	2.17	70.8
302	Residues, lime	1.38	1.59	68.6	77.7	26.6	33.8	19.4		89.6
303	Manure, lime	1.30	1.92	72.0	80.3	28.3	36.3	19.6	2.57	104.3
304	Cover crop, manure, lime	1.38	2.02	75.6	83.1	26.1	40.4	22.3	2.03	103.3
305	Lime	1.20	1.75	70.5	78.3	22.5	36.6	21.2	1.83	92.1
306	Lime, phosphorus	1.21	1.65	69.7	84.4	32.7	40.6	22.2	2.64	98.2
307	Res., lime, phosphorus	1.16	1.55	74.0	84.1	27.5	41.2	24.1		103.2
308	Manure, lime, phosphorus	1.25	1.63	73.9	86.1	33.9	39.7	21.6	3.25	107.9
309	Cover crop, manure, lime, phosphorus	1.55	2.03	83.9	87.8	28.9	44.9	24.9	3.13	106.0
310	Lime	1.75	2.25	84.3	85.6	31.6	39.8	22.4	2.74	93.0
311	Lime, phosphorus, potassium	2.10	2.41	86.9	87.8	32.3	44.3	24.5	3.59	101.9
312	Residues, lime, phosphorus, potassium	1.55	1.91	75.8	81.2	25.9	41.8	23.2		98.4
313	Manure, lime, phosphorus, potassium	1.16	1.53	68.4	77.9	31.3	35.8	23.0	3.28	108.8
314	Cover crop, manure, lime, phos., potas.	1.50	1.52	70.6	81.7	27.7	42.0	23.1	3.57	106.9
315	Lime	1.90	1.97	74.1	85.1	30.6	36.8	21.6	2.47	90.6
316	Residues	1.82	1.82	67.7	80.6	26.7	34.2	22 9		82.1
317	Residues, phosphorus	1.95	2.00	59.1	83.3	31.1	44.9	27.0		99.2
318	Residues, phosphorus, potassium	2.65	2.18	66.8	73.6	25.8	43.3	29.1		113.2
319	Residues, lime, nitrogen, phos., potas.	4.15	2.37	71.2	84.7	32.7	43.8	24.9		104.1
320	None	1.46	1.56	59.6	72.8	31.3	28.5	15.8	1.46	79.1
Increase for residues									—2.46	5.8
Increase for manure										16.7
Increase for phosphorus		.01	—.05	1.2	5.1	4.8	6.0	2.9	.86	8.6
Increase for potassium		.37	.14	—1.6	—4.7	—2.2	—.8	.6	.47	2.9
Increase for nitrogen		1.50	.19	4.4	11.1	6.9	.5	—4.2		—9.1

was used until crops had been grown for four years and the data had been thus accumulated from which to compute the proper applications of manure. The live-stock system was not fully under way on all series until 1912 (see lower parts of tables), when the average increase from the manure varied from ½ bushel of wheat to nearly 17 bushels of corn.

On Plots 4, 9, and 14 cover crops are grown as indicated in the tables, but the results thus far secured do not justify advising this practice, as may be seen by comparing these plots with Plots 3, 8, and 13, respectively.

At the beginning of this experiment this field was all in timothy sod. Series 300 was not broken during the first two years, but ½ ton of raw rock phosphate per acre was applied as top-dressing. This produced practically no effect,—a result to be expected. A ton of phosphate per acre applied to Series 200 produced no effect on the oats seeded on timothy sod in 1904 and but little effect on the wheat which followed in 1905. Beginning with Series 100 in 1904, Series 300 in 1906, and Series 200 in 1908, the regular plan has been to apply 1½ tons of raw rock phosphate (375 pounds of phosphorus) per acre every six years before plowing for corn, in addition to the partial applications made as stated above. This plan has been followed essentially,

and will be continued until the phosphorus content of the plowed soil is at least doubled, but ultimately the amounts applied for each rotation will be reduced to supply only about as much as is removed in the crops grown, and of course the annual expense for this element will then decrease accordingly.

Potassium is applied in the form of potassium sulfate, 100 pounds per acre of the sulfate (containing 42 pounds of potassium) being used for each year in the rotation. The application is made only in connection with the phosphate in order to ascertain whether its use in this way is profitable, there being no doubt that it would be unprofitable if used alone.

In order to help settle the question whether commercial nitrogen could be used with profit, Plot 19 in each series has received nitrogen at the rate of 25 pounds per acre per annum. Nearly the total amount for the first four years was applied in 1904, but since 1907 the applications have been made annually. The nitrogen has been applied in addition to crop residues, phosphorus, potassium, and limestone.

Table 9.—Galesburg Experiment Field: Financial Statement

(Value of increase from three acres)

Series 100....	Corn	Corn	Oats	Wheat	Clover	Grass	Corn	Corn	Oats	Average 1907 to 1912
Series 200.....	Oats	Wheat	Clover	Grass	Corn	Corn	Oats	Clover	Wheat	
Series 300.....	Grass	Grass	Corn	Corn	Oats	Wheat	Wheat	Clover	Corn	
Years	1904	1905	1906	1907	1908	1909	1910	1911	1912	
For residues..					$-13.14[1]	$-5.34[1]	$ 1.13[2]	$-23.46	$ -.16	
For manure...					2.70[1]	2.90[1]	3.57[2]	5.25[2]	8.16	
For phosph'r's	$ 1.33	$ 3.93	$2.70	$6 77	7.20	7.42	4.85	6.14	11.49	$7.31
For potassium	5.06	3.67	3.41	.14	-1.22	-.13	2.00	4.13	1.06	1.00
For nitrogen..	12.93	.97	4.00	6.31	3.98	3.32	-.90	.31	-4.12	1.48

[1]One crop only.
[2]Two crops only.

In Table 9 is given a financial summary of the results thus far secured from the Galesburg field. Three facts are clearly brought out by the data:

First.—Commercial nitrogen at 15 cents a pound has never paid its cost, and as the system of providing "home-grown" nitrogen in crop residues has developed, the effect of commercial nitrogen has decreased, so that as an average of the last five years it has paid back only 4 percent of its annual cost.

Second.—Potassium, likewise, has never paid its cost, but during the early years, when no adequate provision was made for decaying organic matter, the soluble potassium salt produced a very marked effect, due in part, no doubt, to the fact that it helped to dissolve and make available the raw phosphate always applied with it. With the subsequent increase in decaying organic matter, the effect of potassium has been greatly reduced. As an average of the last six years, potassium costing $7.50 has paid back only $1.

Third.—Phosphorus applied in fine-ground natural rock phosphate in part as top-dressing, and with no adequate provision for decaying organic matter, paid only 47 percent on the investment as an average of the first three years. But it should be kept in mind that the word *investment* is here used in its proper sense, for the phosphorus that was removed in the increase produced was less than 2 percent of the amount applied, and that removed in the total crops, less than one-third. During the last six years, however, the phosphorus has paid 130 percent on the investment, even tho two-thirds of the application remains to positively enrich the soil.

The results from the Galesburg experiment field furnish some interesting and valuable illustrations of the danger of drawing incorrect conclusions from field-culture experiments conducted for a short time only and without comprehensive knowledge of the factors involved. Thus, the first year the effect of potassium ($5.06) was four times, and that of nitrogen ($12.93) ten times as great as the effect of phosphorus ($1.33); whereas in the last year the effect of phosphorus ($11.49) was eleven times that of potassium ($1.06), while commercial nitrogen applied in addition to the crop residues appears to have been detrimental. These facts only support the following statement quoted on page 208 of Bulletin 123, "The Fertility in Illinois Soils":

"In considering the general subject of culture experiments for determining fertilizer needs, emphasis must be laid on the fact that such experiments should never be accepted as the sole guide in determining future agricultural practice. If the culture experiments and the ultimate chemical analysis of the soil agree in the deficiency of any plant-food element, then the information is conclusive and final; but if these two sources of information disagree, then the culture experiments should be considered as tentative and likely to give way with increasing knowledge and improved methods to the information based on chemical analysis, which is absolute."[1]

THE SUBSURFACE AND SUBSOIL

In Tables 10 and 11 are recorded the amounts of plant food in the subsurface and the subsoil strata of the McDonough county soils, but it should be remembered that these supplies are of little value unless the top soil is kept rich. Probably the most important information contained in these tables is that the upland timber soils are usually more strongly acid in the subsurface and the subsoil than in the surface. This emphasizes the importance of having plenty of limestone in the surface soil to neutralize the acid moisture that rises from the lower strata by capillary action during times of partial drouth, which are critical periods in the life of such plants as clover. Thus, while the common brown silt loam prairie soil is practically neutral, the upland timber soil of similar topography is already in need of limestone; and, as already explained, it is much more deficient in phosphorus and nitrogen than is the common prairie soil.

[1]Taken from "Culture Experiments for Determining Fertilizer Needs," by C. G. H. in Cyclopedia of American Agriculture, Volume I, page 475.

TABLE 10.—FERTILITY IN THE SOILS OF McDONOUGH COUNTY

Average pounds per acre in 4 million pounds of subsurface soil (about 6⅔ to 20 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone requir'd
	Upland Prairie Soils								
526	Brown silt loam	68 172	5 896	1 956	67 664	22 968	21 464		200
520	Black clay loam	93 120	7 467	2 693	59 987	26 133	35 413		40
528	Brown-gray silt loam on tight clay	45 320	3 920	1 600	65 000	17 440	15 880		160
525.1	Black silt loam on clay.......	68 080	5 480	1 880	62 920	25 840	28 400		80
	Upland Timber Soils								
534	Yellow-gray silt loam	17 510	2 150	1 420	72 720	20 200	15 090		750
535	Yellow silt loam	13 520	1 960	1 700	75 620	23 640	14 640		2 190
532	Light gray silt loam on tight clay	9 680	1 680	1 680	72 840	21 280	14 000		6 880
	Swamp and Bottom-Land Soils								
1326	Deep brown silt loam..	58 920	6 040	3 040	74 840	19 080	20 240		80

TABLE 11.—FERTILITY OF THE SOILS OF McDONOUGH COUNTY

Average pounds per acre in 6 million pounds of subsoil (about 20 to 40 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone requir'd
	Upland Prairie Soils								
526	Brown silt loam	38 430	4 056	2 520	99 246	47 874	34 284		432
520	Black clay loam	45 660	3 580	3 360	93 560	45 100	47 600	4 240	
528	Brown-gray silt loam on tight clay.	32 160	3 480	2 460	91 500	42 180	30 060		240
525.1	Black silt loam on clay.......	16 560	2 700	2 520	97 380	46 380	40 740		60
	Upland Timber Soils								
534	Yellow-gray silt loam	16 590	2 550	2 520	105 090	39 630	21 465		6 495
535	Yellow silt loam	4 860	2 130	3 030	114 300	41 640	27 000		3 750
532	Light gray silt loam on tight clay	5 160	2 520	2 940	106 860	44 940	25 740		4 620
	Swamp and Bottom-Land Soils								
1326	Deep brown silt loam	25 260	2 940	4 620	108 780	27 360	18 780		16 800

INDIVIDUAL SOIL TYPES

(a) UPLAND PRAIRIE SOILS

The upland prairie soils of McDonough county comprize 374 square miles, or 65 percent of the entire area of the county. They are usually dark in color owing to their large organic-matter content.

The accumulation of organic matter in the prairie soils is due to the growth of prairie grasses that once covered them, and whose network of roots has been protected from complete decay by the imperfect aeration afforded by the covering of fine soil material and the moisture it contains. On the native prairies, the tops of these grasses were usually burned or became almost completely decayed. From a sample of virgin sod of "blue stem," one of the most common prairie grasses, it has been determined that an acre of this soil to a depth of 7 inches contained 13½ tons of roots. Many of these roots died each year and by partial decay formed the humus of these dark prairie soils.

Brown Silt Loam (526)

The brown silt loam is the most important as well as the most extensive type of soil in McDonough county. It covers an area of 318.18 square miles (203,637 acres), or 55.44 percent of the entire area of the county.

This type is generally sufficiently rolling for fair natural surface drainage, altho there are some exceptions where the land is so flat as to require thoro artificial drainage. Draws or swales are frequently "seepy." To carry off this seepage from the higher land, there should be at least one line of tile, and two may sometimes be necessary.

The surface soil, 0 to 6⅔ inches, is a brown silt loam varying from a yellowish brown on the more rolling areas to a dark brown or black on the more nearly level and poorly-drained areas. In physical composition it varies to some extent, but it normally contains 70 to 80 percent of the different grades of silt. The clay content, usually 10 to 12 percent, increases as the type approaches black clay loam (520) and black silt loam on clay (525.1), naturally becoming greater in the poorly-drained areas. The sand content varies from 8 to 20 percent and is usually of the finer grades. The organic-matter varies from 3 to 5 percent, averaging 4.2 percent, or 42 tons per acre. Where this type passes into the brown-gray silt loam on tight clay (528) or the yellow-gray silt loam (534), the amount of organic matter becomes lower. The forest trees that once grew on the upland in this climate reduced the organic matter and ultimately changed the original brown prairie soil into yellow-gray silt loam. These forests consisted quite largely of black walnut, with such other trees as wild cherry, hackberry, ash, and elm. A black-walnut soil is generally recognized by farmers as being one of the best timber soils. It still contains, as a rule, a large amount of the organic matter that accumulated from the prairie grasses.

The subsurface is represented by a stratum varying from 5 to 14 inches in thickness. This variation is due to changing topography, the stratum being thinner on the more rolling areas and thicker on the level areas. In physical composition the subsurface varies the same as the surface soil, but it usually contains a slightly larger amount of clay and a much smaller amount of organic matter. In some places, it may become quite heavy, as where the brown silt loam grades toward the black silt loam on clay (525.1). In color

the subsurface varies from a dark brown or almost black to a light or a yellowish brown. It usually becomes lighter with depth and passes into the yellow subsoil.

The natural subsoil begins 12 to 21 inches beneath the surface and extends to an indefinite depth, but it is usually sampled to a depth of 40 inches. It varies from a yellow to a drabbish yellow, clayey silt. In the level or nearly level areas, it is of a drab color, while in the more rolling areas, where better drainage has allowed higher oxidation of the iron to take place, it is of a yellow or brownish yellow color. The upper part of the subsoil usually contains more clay than the lower part.

The subsoil is usually pervious to water, permitting good drainage, but where this type grades toward brown-gray silt loam on tight clay (528), a phase is found that is rather hard to drain.

While this type is in fair physical condition, yet continuous cropping to corn, or corn and oats, with the burning of the stalks, is destroying the tilth; the soil is becoming more difficult to work; it runs together more; and aeration, granulation, and absorption of moisture do not take place as readily as formerly. This condition of poor tilth may become serious if the present methods of management continue; it is already one of the factors that limit the crop yields. The remedy is to increase the organic-matter content by plowing under crop residues, such as corn stalks, straw, and clover, instead of selling them from the farm or burning them, as is so often practiced at present. Where corn follows corn, the stalks should be thoroly cut up with a sharp disk or stalk cutter, and turned under. Likewise, the straw should be returned to the land in some practical way, either directly or in manure. Clover should be one of the crops grown in the rotation, and it should be plowed under directly or in manure instead of being sold as hay, except when manure can be brought back.

The addition of fresh organic matter is not only of great value in improving the physical condition of this type of soil, but it is of even greater importance because of its nitrogen content and because of its power, as it decays, to liberate potassium from the inexhaustible supply in the soil, and phosphorus from the phosphate contained in or applied to the soil.

For permanent profitable systems of farming on brown silt loam, phosphorus should be applied liberally, and sufficient organic matter should be provided to furnish the necessary amount of nitrogen. On the ordinary type, limestone is already becoming deficient. In live-stock farming an application of two tons of limestone and one-half ton of fine-ground rock phosphate per acre every four years, with the return to the soil of all manure made from a rotation of corn, corn, oats, and clover, will maintain the fertility of this type, altho heavier applications of phosphate may well be made during the first two or three rotations. If grain farming is practiced, the rotation may be wheat, corn, oats, and clover, with an extra seeding of clover as a cover crop in the wheat, to be plowed under late in the fall or in the following spring for corn; and most of the crop residues, with all clover except the seed, should also be plowed under. In either system, alfalfa may be grown on a fifth field and mowed every five years, the hay being fed or sold. (For results of field experiment on the brown silt loam prairie, see Tables 3 to 9.)

Black Clay Loam (520)

The black clay loam represents in part the originally swampy and poorly-drained land (the flat prairie) of the upper Illinois glaciation. It is frequently called "gumbo" because of its sticky character. Its formation in the low places is due to the accumulation of organic matter and the washing in of clay and fine silt from the slightly higher adjoining lands. This type in McDonough county covers 19.22 square miles (12,301 acres), or 3.35 percent of the total area of the county. In topography it is so flat that in the large areas the problem of getting a sufficient outlet for drainage has caused some difficulty.

The surface stratum is a black, granular, clay loam with an average organic-matter content of 6.75 percent, or 67 tons per acre, the amount varying from 60 to 80 tons. The more luxuriant growth of prairie grasses that once covered this black clay loam, and the preservation of their roots by the moist condition of the soil, has resulted in a greater accumulation of organic matter in this type than in the more rolling types of upland prairie soils.

The surface soil is naturally quite granular. This property of granulation is important to all soils, but especially so to heavy ones, for by it the soil is kept in good tilth and rendered pervious to air and water. If the granules are destroyed by puddling (as they are if the soil is worked or stock are allowed to trample on it while it is wet), they will be formed again by freezing and thawing or by moisture changes (wetting and drying). These natural agencies produce "slaking," as the process is usually termed. If, however, the organic-matter or the lime content becomes low, this tendency to granulate grows less and the soil becomes more difficult to work.

The subsurface extends to a depth of 10 to 16 inches below the surface stratum. It differs from the surface in color, becoming lighter with depth, the lower part of the stratum passing into a drab or yellowish, silty clay. It is quite pervious to water, owing to the jointing or checking produced by shrinkage in times of drouth. The amount of organic matter varies from 3.8 to 4.6 percent.

The subsoil is usually a drab or dull yellow, silty clay, but locally it may be a yellow, clayey silt or even a silt. As a rule, the iron is not highly oxidized, because of poor drainage. The checking and jointing in the subsoil make it readily permeable to water and consequently easy to drain. In some areas the subsoil contains large numbers of limestone concretions (calcium carbonate).

Black clay loam presents many variations. Here, as elsewhere, the boundary lines between different soil types are not always distinct, but types frequently pass from one to another very gradually, thus giving an intermediate zone of greater or less width. Variations between black clay loam (520) and brown silt loam (526) are very likely to occur since they are usually adjoining types. This gives a lighter phase of black clay loam (520), with a smaller organic-matter content than the average, or a heavier phase of brown silt loam (526), darker, and with a larger amount of organic matter than the average. (In chemical composition, the gradation zone is intermediate between the two normal, adjoining types.) Again, in some areas of black clay loam there has been enough silty material washed in from the surrounding higher lands, especially near the edges of the areas, to modify the character of the surface soil. This change is taking place more rapidly now, with the annual cultivation of the soil, than formerly, when washing was largely prevented by prairie grasses.

Drainage is the first requirement of this type. Altho it usually has but little slope, yet because of its perviousness it affords a good chance for tile drainage. Keeping the soil in good physical condition is very essential, and thoro drainage helps to do this to a great extent. As the organic matter is destroyed by cultivation and nitrification and the lime removed by cropping and leaching, the physical condition of the soil becomes poorer, and consequently it becomes more difficult to work. Both the organic matter and the lime tend naturally to develop a granular condition, but they are especially effective when aided by careful and well-timed cultivation. The organic matter should be maintained by turning under manure, clover, and crop residues, such as corn stalks and straw. Too often the crop residues are burned or put back in such a way as not to produce the greatest benefit. Straw is too frequently left in lots until the larger part of the organic matter is lost by fermentation and leaching. Ground limestone applied liberally when the soil becomes acid, will also help to keep the soil in good physical condition.

While black clay loam is one of the best soils in the state, the clay and humus contained in it give it the property of shrinkage and expansion to such a degree as to be somewhat objectionable at times. When the soil is wet, these constituents expand, and when the moisture evaporates or is used by crops, they shrink. This results in the formation of cracks up to two inches or more in width and extending with lessening width to a foot or more in depth. These cracks allow the soil strata to dry out rapidly, and as a result, the crop is injured thru lack of moisture. They may also do considerable damage by "blocking out" hills of corn and severing the roots. While cracking may not be prevented entirely, yet good tilth, with a soil mulch, will do much toward that end.

This type is fairly well supplied with plant food, which is usually liberated with sufficient rapidity by a good rotation and by the addition of moderate amounts of organic matter. The amount of organic matter added must be increased, of course, with continued farming, until the nitrogen supplied is equal to that removed. Altho the addition of phosphorus is not expected to produce marked profit, it is likely to pay its cost in the second or third rotation, and even by maintaining the productive power of the land, the capital invested is protected.

This type is rich in magnesium and calcium, and the subsoil usually contains plenty of carbonates. With continued cropping and leaching, applications of limestone will be needed. (No field experiments have been conducted as yet on this type of soil.)

Brown-Gray Silt Loam on Tight Clay (528)

Brown-gray silt loam on tight clay is found principally in the southwest part of McDonough county. It comprizes 29.25 square miles (18,720 acres), or 5.1 percent of the total area.

The surface soil, 0 to 6⅔ inches, is a brown or grayish brown silt loam containing some fine sand and coarse silt, which give it a fine texture. The organic-matter content varies somewhat according to the relation of the type to other types, being greater where it approaches brown silt loam (526) or black silt loam on clay (525.1), and less where it grades toward yellow-gray silt loam (534); the average is about 3.5 percent.

The subsurface is represented by a stratum 10 to 12 inches thick. In color it varies from a brown to a gray or grayish brown, the upper part of

the stratum usually being brown, and the lower part, gray or grayish brown. It differs from the surface stratum principally in the amount of organic matter it contains.

The natural subsoil consists of a stratum of tight clay beginning 16 to 18 inches beneath the surface and varying in thickness from 10 to 20 inches. It is usually underlain by a pervious silt.

This type is rather flat, and much of it needs drainage. Owing to the impervious character of the subsoil, it is in greater need of tile drainage than is the brown silt loam, and the lines of tile should be placed nearer each other. For efficient drainage, they should not be over 5 rods apart, and 3 or 4 rods is better. Care should be taken to increase the amount of organic matter by the proper rotation of crops, by turning under crop residues, and by the application of farm manure. Deep-rooting crops, such as red, mammoth, or sweet clover, should be grown in order to loosen up, in a measure, the tight clay subsoil and promote drainage and aeration.

From Table 2 it will be seen that the surface soil contains only 900 pounds of phosphorus per acre. To increase the amount of this element, liberal applications of fine-ground rock phosphate should be made in connection with the decaying organic matter, as on the brown silt loam. Limestone should be applied at the rate of 2 to 3 tons per acre every four to six years. The initial application may well be 1 ton of phosphate and 4 tons of limestone.

On recently established twenty-acre experiment fields on this type of soil at Carthage in Hancock county and at Clayton in Adams county, organic manures increased the yield of corn, in the very dry season of 1912, from 30.6 to 40.5 bushels at Carthage and from 36.8 to 46.7 bushels at Clayton. Where both organic manures and rock phosphate were applied, the average yield on the Carthage field was increased to 48.1 bushels and on the Clayton field to 55.6 bushels. Thus it is seen that the average increase in the corn yield resulting from the use of organic manures was 9.9 bushels per acre, and from the use of organic manures reinforced with rock phosphate, 18.2 bushels. Limestone applied subsequently is showing marked benefit in 1913 at both Carthage and Clayton, especially on the growth of sweet clover, which is used as a green-manure cover crop. Thus the data already secured are in agreement with the analytical data for this soil type.

Black Silt Loam on Clay (525.1)

Black silt loam on clay comprizes 7.24 square miles (4,634 acres), or 1.26 percent of the area of McDonough county. It occurs mostly in small areas over the county, often in proximity to the brown-gray silt loam on tight clay (528). In topography it is usually about the same as the black clay loam (520), but it does not permit of as good underdrainage because of the somewhat tight character of the subsoil. This is especially true where it approaches the brown-gray silt loam on tight clay (528).

The surface soil, 0 to 6⅔ inches, is a black silt loam, varying on the one hand toward black clay loam (520), and on the other to brown silt loam (526) or brown-gray silt loam on tight clay (528). When thoroly drained, it is naturally granular and of good tilth, but the same precautions must be taken to keep it in good physical condition as are necessary with black clay loam (520). The organic-matter content averages about 5.5 percent, or 55 tons per acre.

The subsurface stratum varies from 8 to 14 inches in thickness. In color it varies from black to dark brown near the top of the stratum, to drab or yellowish drab near the bottom. The proportion of clay increases with depth.

The subsoil resembles that of the black clay loam (520) except that it is heavier.

Drainage is one of the first requirements of this type.

For maintaining good tilth one of the most practical means is the incorporation of organic matter. This can be accomplished by providing a proper rotation of crops (which should include clover or some other legume), and turning under the legume, together with the crop residues (corn stalks and straw). Such organic matter or farm manure will not only help in maintaining good tilth but it will also supply the amount of nitrogen required in permanent economic systems of general farming.

In phosphorus content, black silt loam on clay lies between the brown silt loam and the brown-gray silt loam on tight clay. Fine-ground rock phosphate should be applied in connection with the organic manures at the rate of about one-half ton per acre every four years. The initial application may well be one ton or more.

This type of soil is practically neutral, which means that it is not distinctly acid and yet that it contains no limestone. For the best results, especially in the growing of legume crops, limestone should be applied. Two tons per acre every four or five years will maintain a sufficient supply in the soil.

(b) Upland Timber Soils

In the soils of the upland forests, there is found no such quantity of roots as is found in the prairie soils. The vegetable material consists of leaves and twigs which fall upon the surface and either are burned by forest fires or undergo almost complete decay. There is very little chance for these to become mixed with the soil. As a result, the organic-matter content of the upland timber soils has been lowered until in some parts of the state a low condition of apparent equilibrium has been reached.

Yellow-Gray Silt Loam (534)

Yellow-gray silt loam in McDonough county occurs in the outer timber belts along the streams, and covers 39 square miles (24,960 acres), or 6.79 percent of the county. In topography it is sufficiently rolling for good surface drainage and without much tendency to wash if proper care is taken.

The surface soil, 0 to 6⅔ inches, is a gray to yellowish gray silt loam, incoherent and mealy but not granular. The amount of organic matter contained in it varies from 1.8 to 3.4 percent with an average of 2.3 percent or 23 tons per acre. This variation is due to the relation of the type to other types, the content of organic matter increasing where it grades into brown silt loam (526) and brown-gray silt loam on tight clay (528), and decreasing where it passes into yellow silt loam (535) and light gray silt loam on tight clay (532). In some places, erosion has reduced the amount of organic matter.

The subsurface stratum varies from 3 to 10 inches in thickness, erosion having reduced its depth on the more rolling areas. In color it is a gray, grayish yellow, or yellow silt loam, somewhat pulverulent, but becoming more coherent and plastic with depth.

The subsoil is a yellow or grayish yellow, clayey silt or silty clay, somewhat plastic when wet, but friable when only moist, and pervious to water.

In the management of this yellow-gray silt·loam, one of the most essential points is the maintenance or increase of organic matter. This is necessary in order to supply nitrogen and liberate mineral plant food, to give better tilth, to prevent "running together," and, on some of the more rolling phases, to prevent washing. Another essential is the neutralization of the acidity of the soil by the application of ground limestone, so that clover, alfalfa, and other legumes may be grown more successfully. The initial application may well be 4 or 5 tons per acre, after which 2 tons per acre every four or five years will be sufficient. Since the soil is poor in phosphorus, this element should be applied, preferably in connection with farm manure or clover plowed under. In permanent systems of farming, fine-ground natural rock phosphate will be found the most economical form in which to supply the phosphorus.

For definite results from the most practical field experiments upon typical yellow-gray silt loam, we must go down into "Egypt," where the people of Saline county, especially those in the vicinity of Raleigh and Galatia, have provided the University with a very suitable tract of this type of soil for a permanent experiment field. There, as an average of triplicate tests each year, the yield of corn on untreated land was 25.3 bushels in 1910, 23.6 bushels in 1911, and 22 bushels in 1912; while on duplicate plots treated with heavy applications of limestone and a limited amount of organic manures, the corresponding yields were 41.4 bushels in 1910, 41.3 bushels in 1911, and 50.1 bushels in 1912, the corn being grown on a different series of plots every year in a four-year rotation of wheat, corn, oats, and clover. About the same proportionate increases were produced in wheat and hay, and the effect on oats was also marked. Owing to the low supply of organic matter, phosphorus produced no benefit, as an average, during the first two years; but with increasing applications of organic matter, the effect of phosphorus is seen in the crops of 1912 and 1913. Of course a single four-year rotation cannot be practiced in less than four years, and the full benefit of a system of rotation and soil treatment is not to be expected before the third or fourth four-year period.

While limestone is the material first needed for the economic improvement of the more acid soils of southern Illinois, with organic manures and phosphorus to follow in order, the less acid soils of the west-central part of the state are first in need of phosphorus, in which they are relatively about as deficient as the acid soils are in lime. Organic matter is also greatly needed by these less acid soils.

Table 12 shows in detail eleven years' results secured from the Antioch soil experiment field located in Lake county on the yellow-gray silt loam of the late Wisconsin glaciation. In acidity, this type in McDonough county is intermediate between the similar soils in Saline and Lake counties, but no experiment field has been conducted on this important soil type in the upper Illinois glaciation, in which McDonough county is situated.

The Antioch field was started in order to learn as quickly as possible just what effect would be produced by the addition to this type of soil, of nitrogen, phosphorus, and potassium, singly and in combination. These elements have all been added in commercial form. Only a small amount of lime was applied at the beginning; and with the abnormality of Plot 101, and with an abundance of limestone in the subsoil (a common condition in the late Wis-

TABLE 12.—CROP YIELDS IN SOIL EXPERIMENTS, ANTIOCH FIELD

Yellow-gray silt loam, undulating timberland; late Wisconsin glaciation		Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912
Plot	Soil treatment applied	Bushels per acre										
101	None[1]	44.8	36.6	17.8	18.5	35.9	12.4	65.6	12.2	5.2	34.4	21.3
102	Lime	45.1	38.9	12.8	10.3	31.5	9.5	61.6	11.7	3.0	24.6	17.5
103	Lime, nitrogen	46.3	40.8	2.8	17.8	37.8	6.4	60.3	13.0	1.4	10.4	24.4
104	Lime, phosphorus	50.1	53.6	12.5	35.8	57.4	13.4	70.9	23.3	6.8	37.4	49.1
105	Lime, potassium	48.2	50.2	9.7	21.7	34.9	12.9	62.5	13.5	4.6	20.4	18.8
106	Lime, nitro., phos.	56.6	62.7	15.9	15.2	59.3	20.9	49.1	33.8	6.0	37.0	46.9
107	Lime, nitro., potas.	52.1	54.9	10.3	11.8	39.0	11.1	52.6	21.0	1.6	7.0	16.9
108	Lime, phos., potas.	60.7	66.0	19.7	28.7	59.1	18.3	59.4	26.2	3.2	42.2	35.9
109	Lime, nitro., phos. potas.	61.2	69.1	31.9	18.0	65.9	31.4	51.9	30.5	3.0	44.2	31.9
110	Nitro., phos., potas.	59.7	71.8	37.2	16.3	66.3	28.8	55.9	34.5	4.0	49.0	38.1

Average Increase: Bushels per Acre

	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912
For nitrogen	3.0	4.7	1.6	−8.4	4.8	3.9	−10.1	5.9	−1.4	−6.5	−.3
For phosphorus	9.2	16.7	11.1	9.0	24.6	11.0	−1.4	13.7	2.1	24.6	21.6
For potassium	6.0	11.0	6.9	.3	3.2	5.9	−3.9	2.3	−1.2	1.1	−8.6
For nitro., phos. over phos.	6.5	9.1	3.4	−20.6	1.9	7.5	−21.8	10.5	−.8	−.4	2.2
For phos., nitro. over nitro	10.3	21.9	13.1	−2.6	21.5	14.5	−11.2	20.8	4.6	26.6	22.5
For potas., nitro., phos. over nitro., phos.	4.6	6.4	16.0	2.8	6.6	10.5	2.8	−3.3	−3.0	7.2	−15.0

Value of Crops per Acre in Eleven Years

Plot	Soil treatment applied	Total value of eleven crops	Value of increase
101	None	$112.16	
102	Lime	96.38	$−15.78
103	Lime, nitrogen	97.89	−14.27
104	Lime, phosphorus	157.67	45.51
105	Lime, potassium	111.86	−.30
106	Lime, nitrogen, phosphorus	152.75	40.59
107	Lime, nitrogen, potassium	104.89	−7.27
108	Lime, phosphorus, potassium	160.25	48.09
109	Lime, nitrogen, phosphorus, potassium	164.83	52.67
110	Nitrogen, phosphorus, potassium	172.78	60.62

Value of Increase per Acre in Eleven Years		Cost of increase
For nitrogen	$ 1.51	$165.00
For phosphorus	61.29	27.50
For *nitrogen* and phosphorus over phosphorus	−4.92	165.00
For *phosphorus* and nitrogen over nitrogen	54.86	27.50
For *potassium*, nitrogen, and phosphorus over nitrogen and phosphorus	12.08	27.50

[1]Plot 101, the check plot, is the lowest ground but it is well drained and is appreciably better land than the rest of the field. Plot 102 is a more trustworthy check plot.

consin glaciation), no conclusions can be drawn regarding the effect of lime.

As an average of 44 tests (4 each year for 11 years), liberal applications of commercial nitrogen have produced a slight decrease in crop values, phosphorus has paid back 200 percent of its cost, while each dollar invested in potassium has brought back only 34 cents (a net loss of 66 percent). Thus, while the detailed data show great variation, owing both to some irregularity of soil and to some very abnormal seasons, with three almost complete crop failures (1904, 1907, and 1910), yet the general summary strongly confirms the analytical data in showing the need of applying phosphorus and the profit from its use, and the loss in adding potassium. In most cases commercial nitrogen damaged the small grains by causing the crop to lodge; but in those years when a corn yield of 40 bushels or more was secured by the application of phosphorus either alone or with potassium, then the addition of nitrogen produced an increase.

From a comparison of the results from the Sibley, Bloomington, and Galesburg fields (see pages 10 to 20), we must conclude that better yields are to be secured by providing nitrogen by means of farm manure or legume crops grown in the rotation than by the use of commercial nitrogen, which is evidently too readily available, causing too rapid growth and consequent weakness of straw; and of course the atmosphere is the most economic source of nitrogen where that element is needed for soil improvement in general farming. (See Appendix for detailed discussion of "Permanent Soil Improvement.")

Yellow Silt Loam (535)

In area, yellow silt loam stands second among the soil types of McDonough county, covering 144.41 square miles (92,422 acres), or 25.16 percent of the county. It occurs as the hilly and badly eroded land on the inner timber belts along the streams, usually only in narrow, irregular strips, with arms extending up the small valleys. In topography it is very rolling and in most places so badly broken that it should not be cultivated because of the danger of injury from washing.

The surface soil, 0 to 6⅔ inches, is a yellow or yellowish gray silt loam, pulverulent and mealy. It varies a great deal, owing to recent washing. In some places the natural subsoil may be exposed. The organic-matter content is about 1.9 percent.

The typical subsurface varies in thickness from 0 to 12 inches, the variation being due to the removal of all or part of the surface and subsurface.

The subsoil is a compact, yellow, clayey silt.

In the management of this yellow silt loam, the most important thing is to prevent general surface washing and gullying. If the land is cropped at all, a rotation should be practiced that will require a cultivated crop as little as possible and allow pasture and meadow most of the time. If tilled, the land should be plowed deeply; and contours should be followed as nearly as possible in plowing, planting, and cultivating. Furrows should not be made up and down the slopes. Every means should be employed to maintain and increase the organic-matter content; this will help hold the soil and keep it in good physical condition so that it will absorb a large amount of water and thus diminish the run-off. (See Circular 119, "Washing of Soils and Methods of Prevention.")

Additional treatment recommended for this yellow silt loam is the liberal use of limestone wherever cropping is practiced. This type is quite acid and

very deficient in nitrogen; and the limestone, by correcting the acidity of the soil, is especially beneficial to the clover grown to increase the supply of nitrogen. Where this soil has been long cultivated and thus exposed to surface washing, it is particularly deficient in nitrogen; indeed on such lands the low supply of nitrogen is the factor that first limits the growth of grain crops. This fact is very strikingly illustrated by the results from two pot-culture experiments reported in Tables 13 and 14, and shown photographically in Plates 6 and 7.

In one experiment, a large quantity of the typical worn hill soil was collected from two different places.[1] Each lot of soil was thoroly mixed and put in ten four-gallon jars. Ground limestone was added to all the jars except the first and last in each set, those two being retained as control or check pots. The elements nitrogen, phosphorus, and potassium were added singly and in combination, as shown in Table 13.

As an average, the nitrogen applied produced a yield about eight times as large as that secured without the addition of nitrogen. While some variations

PLATE 6.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND (See Table 13)

TABLE 13.—CROP YIELDS IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND
(Grams per pot)

Pot No.	Soil treatment applied	Wheat	Oats
1	None	3	5
2	Limestone	4	4
3	Limestone, nitrogen	26	45
4	Limestone, phosphorus	3	6
5	Limestone, potassium	3	5
6	Limestone, nitrogen, phosphorus	34	38
7	Limestone, nitrogen, potassium	33	46
8	Limestone, phosphorus, potassium	2	5
9	Limestone, nitrogen, phosphorus, potassium	34	38
10	None	3	5
Average yield with nitrogen		32	42
Average yield without nitrogen		3	5
Average gain for nitrogen		29	37

[1]Soil for wheat pots from loess-covered unglaciated area, and that for oat pots from upper Illinois glaciation.

in yield are to be expected, because of differences in the individuality of seed or other uncontrolled causes, yet there is no doubting the plain lesson taught by these actual trials with growing plants.

The question arises next, Where is the farmer to secure this much-needed nitrogen? To purchase it in commercial fertilizer would cost too much; indeed, under average conditions the cost of the nitrogen in such fertilizers is greater than the value of the increase in crop yields.

There is no need whatever to purchase nitrogen, for the air contains an inexhaustible supply of it, which, under suitable conditions, the farmer can draw upon, not only without cost, but with profit in the getting. Clover, alfalfa, cowpeas, and soybeans are not only worth raising for their own sake, but they have the power to secure nitrogen from the atmosphere if the soil contains limestone and the proper nitrogen-fixing bacteria.

In order to secure further information along this line, another experiment with pot cultures was conducted for several years with the same type of worn hill soil as that used in the former experiment. The results are reported in Table 14.

To three pots (Nos. 3, 6, and 9) nitrogen was applied in commercial form, at an expense amounting to more than the total value of the crops produced. In three other pots (Nos. 2, 11, and 12) a crop of cowpeas was grown during the late summer and fall and turned under before the wheat or oats were planted. Pots 1 and 8 served for important comparisons. After the second catch crop of cowpeas had been turned under, the yield from Pot 2 exceeded that from Pot 3; and in the subsequent years the legume green manures produced, as an average, rather better results than the commercial nitrogen. This experiment confirms that reported in Table 13, in showing the very great need of nitrogen for the improvement of this type of soil, and it also shows that nitrogen need not be purchased but that it can be obtained from the air by growing legume crops and plowing them under as green manure. Of course, the soil can be very markedly improved by feeding the legume crops to live stock and returning the resulting farm manure to the land, if sufficiently frequent crops of legumes are grown and if the farm manure produced is sufficiently abundant and is saved and applied with care.

As a rule, it is not advisable to try to enrich this type of soil in phosphorus, for with the erosion that is sure to occur to some extent, the phosphorus supply will be renewed from the subsoil.

One of the most profitable crops to grow on this land is alfalfa. To get alfalfa well started requires the liberal use of limestone, thoro inoculation with nitrogen-fixing bacteria, and a moderate application of farm manure. If manure is not available, it is well to apply about 500 pounds per acre of acid phosphate, or steamed bone meal, mix it with the soil, by disking if possible, and then plow it under. The limestone (about 5 tons) should be applied after plowing and should be mixed with the surface soil in the preparation of the seed bed. The special purpose of this treatment is to give the alfalfa a quick start in order that it may grow rapidly and thus protect the soil from washing.

Light Gray Silt Loam on Tight Clay (532)

Light gray silt loam on tight clay in McDonough county aggregates only 2.53 square miles (1,619 acres), or .44 percent of the county. It usually appears in small areas chiefly in the southwestern and southern part of the county. In topography this type is flat, with poor drainage, altho not swampy. It was formerly covered with hickory, white oak, and "black jack."

The surface soil, 0 to 6⅔ inches, is a white or very light gray silt loam, incoherent, friable, and porous. Iron concretions are usually present. The organic-matter content is very low, amounting to only 1.4 percent, or 14 tons per acre.

The subsurface is a light gray silt loam extending to a depth of 16 to 18 inches. It becomes more clayey with depth and contains only a very small amount of organic matter.

The subsoil is a tight, compact, clayey silt or silty clay.

Besides being very deficient in organic matter, this type of soil contains no limestone, and consequently is in poor physical condition. It runs together badly, and does not retain moisture well, owing to the strong capillarity in the surface and subsurface strata caused by lack of organic matter.

In the management of this type, ground limestone should be used liberally, rock phosphate should be added, and the content of organic matter should be increased in every practical way. Deep-rooting crops, such as red, mammoth, or sweet clover, will loosen the tight clay subsoil as well as supply the top soil (surface and subsurface strata) with organic matter and nitrogen. Where this type is not well drained, alsike will grow better than red clover. Crop residues should be plowed under or plenty of farm manure supplied. Pasturing is one of the best uses that can be made of this land, and even when used for this purpose it may well be liberally supplied with limestone, organic matter, and phosphorus before being seeded down.

PLATE 7.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND (See Table 14)

TABLE 14.—CROP YIELDS IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND AND NITROGEN-FIXING GREEN MANURE CROPS
(Grams per pot)

Pot No.	Soil treatment	1903 Wheat	1904 Wheat	1905 Wheat	1906 Wheat	1907 Oats
1	None.	5	4	4	4	6
2	Limestone, legume	10	17	26	19	37
11	Limestone, legume, phosphorus	14	19	20	18	27
12	Limestone, legume, phosphorus, potassium	16	20	21	19	30
3	Limestone, nitrogen	17	14	15	9	28
6	Limestone, nitrogen, phosphorus	26	20	18	18	30
9	Limestone, nitrogen, phosphorus, potassium	31	34	21	20	26
8	Limestone, phosphorus, potassium	3	3	5	3	7

(c) Swamp and Bottom-Land Soils

The bottom-land soils are derived from material washed from the upland, and must therefore have some relation to the upland soils. They differ in that they are more variable in physical composition than any single upland type, and the brown color extends into them to a greater depth.

Deep Brown Silt Loam (1326)

The bottom land in McDonough county is made up entirely of deep brown silt loam. It occurs in long, narrow strips varying from a few rods to nearly a mile in width, and occupies 14.02 square miles (8,973 acres), or 2.44 percent of the area of the county. In topography it is flat or with very slight undulations that represent old stream or overflow channels.

The surface soil, 0 to 6⅔ inches, is a brown silt loam containing 4 percent of organic matter, or 40 tons per acre. It is probably easier to maintain the fertility and the organic matter in this deep brown silt loam than in the upland soils, because of its occasional overflow and the consequent deposition of material rich in humus and plant food. In physical composition this type varies from a clay loam to a sandy loam, but the areas of these extreme types, especially of the sandy loam, are so small and so changeable that to show them on the map really does not mean very much, as the next flood may change their boundaries.

The subsurface is also a brown silt loam, becoming lighter in color, and frequently in texture, with depth. It contains an average of 2.5 percent of organic matter.

The subsoil is a yellowish drab silt loam, varying in physical composition either to a clayey silt or to a sandy loam, or even to a sand in the lower subsoil.

Where proper drainage is secured, this type is quite productive. As a rule, where it is subject to frequent overflow nothing is needed except good farming. Even the systematic rotation of crops is not so important where the land is subject to occasional overflow, but where it lies high or is protected from overflow by dikes, a rotation including legume crops should be practiced, and ultimately provision should be made for the enrichment of such protected land in both phosphorus and organic matter, and if acid. in limestone.

APPENDIX

A study of the soil map and the tabular statements concerning crop requirements, the plant-food content of the different soil types, and the actual results secured from definite field trials with different methods or systems of soil improvement, and a careful study of the discussion of general principles and of the descriptions of individual soil types, will furnish the most necessary and useful information for the practical improvement and permanent preservation of the productive power of every kind of soil on every farm in the county.

More complete information concerning the most extensive and important soil types in the great soil areas in all parts of Illinois is contained in Bulletin 123, "The Fertility in Illinois Soils," which contains a colored general survey soil map of the entire state.

Other publications of general interest are:

Bulletin No. 76, "Alfalfa on Illinois Soils"
Bulletin No. 94, "Nitrogen Bacteria and Legumes"
Bulletin No. 115, "Soil Improvement for the Worn Hill Lands of Illinois"
Bulletin No. 125, "Thirty Years of Crop Rotation on the Common Prairie Lands of Illinois"
Circular No. 110, "Ground Limestone for Acid Soils"
Circular No. 127, "Shall We Use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils?"
Circular No. 129, "The Use of Commercial Fertilizers"
Circular No. 149, "Some Results of Scientific Soil Treatment" and "Methods and Results of Ten Years' Soil Investigation in Illinois"
Circular No. 165, "Shall We Use 'Complete' Commercial Fertilizers in the Corn Belt?"

NOTE.—Information as to where to obtain limestone, phosphate, bone meal, and potasium salts, methods of application, etc., will also be found in Circulars 110 and 165.

Soil Survey Methods

The detail soil survey of a county consists essentially of indicating on a map the location and extent of the different soil types; and, since the value of the survey depends upon its accuracy, every reasonable means is employed to make it trustworthy. To accomplish this object three things are essential: first, careful, well-trained men to do the work; second, an accurate base map upon which to show the results of their work; and, third, the means necessary to enable the men to place the soil-type boundaries, streams, etc., accurately upon the map.

The men selected for the work must be able to keep their location exactly and to recognize the different soil types, with their principal variations and limits, and they must show these upon the maps correctly. A definite system is employed in checking up this work. As an illustration, one soil expert will survey and map a strip 80 rods or 160 rods wide and any convenient length, while his associate will work independently on another strip adjoining this area, and, if the work is correctly done, the soil type boundaries will match up on the line between the two strips.

An accurate base map for field use is absolutely necessary for soil mapping. The base maps are made on a scale of one inch to the mile. The official data of the original or subsequent land survey are used as a basis in the construction of these maps, while the most trustworthy county map available is used in locating temporarily the streams, roads, and railroads. Since the best of these published maps have some inaccuracies, the location of every road, stream, and railroad must be verified by the soil surveyors, and cor-

rected if wrongly located. In order to make these verifications and corrections, each survey party is provided with an odometer for measuring distances, and a plane table for determining directions of roads, railroads, etc.

Each surveyor is provided with a base map of the proper scale, which is carried with him in the field; and the soil-type boundaries, additional streams, and necessary corrections are placed in their proper locations upon the map while the mapper is on the area. Each section, or square mile, is divided into 40-acre plots on the map, and the surveyor must inspect every ten acres and determine the type or types of soil composing it. The different types are indicated on the map by different colors, pencils for this purpose being carried in the field.

A small auger 40 inches long forms for each man an invaluable tool with which he can quickly secure samples of the different strata for inspection. An extension for making the auger 80 inches long is taken by each party, so that any peculiarity of the deeper subsoil layers may be studied. Each man carries a compass to aid in keeping directions. Distances along roads are measured by an odometer attached to the axle of the vehicle, while distances in the field off the roads are determined by pacing, an art in which the men become expert by practice. The soil boundaries can thus be located with as high a degree of accuracy as can be indicated by pencil on the scale of one inch to the mile.

SOIL CHARACTERISTICS

The unit in the soil survey is the soil type, and each type possesses more or less definite characteristics. The line of separation between adjoining types is usually distinct, but sometimes one type grades into another so gradually that it is very difficult to draw the line between them. In such exceptional cases, some slight variation in the location of soil-type boundaries is unavoidable.

Several factors must be taken into account in establishing soil types. These are (1) the geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial, or cumulose; (2) the topography, or lay of the land; (3) the native vegetation, as forest or prairie grasses; (4) the structure, or the depth and character of the surface, subsurface, and subsoil; (5) the physical, or mechanical, composition of the different strata composing the soil, as the percentages of gravel, sand, silt, clay, and organic matter which they contain; (6) the texture, or porosity, granulation, friability, plasticity, etc.; (7) the color of the strata; (8) the natural drainage; (9) agricultural value, based upon its natural productiveness; (10) the ultimate chemical composition and reaction.

The common soil constituents are indicated in the following outline:

CONSTITUENTS OF SOILS

Soil Constituents	Organic Matter	Comprising undecomposed and partially decayed vegetable material
	Inorganic Matter	Clay..........................001 mm.[1] and less
		Silt..........................001 mm. to .03 mm.
		Sand..........................03 mm. to 1. mm.
		Gravel........................1. mm. to 32 mm.
		Stones........................32. mm. and over

[1]25 millimeters equal 1 inch.
Further discussion of these constituents is given in Circular 82.

Groups of Soil Types

The following gives the different general groups of soils:

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or silt.

Peaty loams—15 to 35 percent of organic matter mixed with much sand and silt and a little clay.

Mucks—15 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 25 percent of clay, usually mixed with much silt.

Clay loams—Soils with from 15 to 25 percent of clay, usually mixed with much silt and some sand.

Silt loams—Soils with more than 50 percent of silt and less than 15 percent of clay, mixed with some sand.

Loams—Soils with from 30 to 50 percent of sand mixed with much silt and a little clay.

Sandy loams—Soils with from 50 to 75 percent of sand.

Fine sandy loams—Soils with from 50 to 75 percent of fine sand mixed with much silt and little clay.

Sands—Soils with more than 75 percent of sand.

Gravelly loams—Soils with 15 to 50 percent of gravel with much sand and some silt.

Gravels—Soils with more than 50 percent of gravel.

Stony loams—Soils containing a considerable number of stones over one inch in diameter.

Rock outcrop—Usually ledges of rock having no agricultural value.

More or less organic matter is found in nearly all the above classes.

Supply and Liberation of Plant Food

The productive capacity of land in humid sections depends almost wholly upon the power of the soil to feed the crop; and this, in turn, depends both upon the stock of plant food contained in the soil and upon the rate at which this is liberated, or rendered soluble and available for use in plant growth. Protection from weeds, insects, and fungous diseases, tho exceedingly important, is not a positive but a negative factor in crop production.

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but the rate of liberation is governed by many factors, some of which may be controlled by the farmer, while others are largely beyond his control. Chief among the important controllable factors which influence the liberation of plant food are limestone and decaying organic matter, which may be added to the soil by direct application of ground limestone and farm manure. Organic matter may be supplied also by green-manure crops and crop residues, such as clover, cowpeas, straw, and cornstalks. The rate of decay of organic matter depends largely upon its age and origin, and it may be hastened by tillage. The chemical analysis shows correctly the total organic carbon, which represents, as a rule, but little more than half the organic matter; so that 20,000 pounds of organic carbon in the plowed soil of an acre correspond to nearly

20 tons of organic matter. But this organic matter consists largely of the old organic residues that have accumulated during the past centuries because they were resistant to decay, and 2 tons of clover or cowpeas plowed under may have greater power to liberate plant food than the 20 tons of old, inactive organic matter. The recent history of the individual farm or field must be depended upon for information concerning recent additions of active organic matter, whether in applications of farm manure, in legume crops, or in grass-root sods of old pastures.

Probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that with the normal rainfall of Illinois the productive power of the land depends primarily upon the stock of plant food contained in the soil and upon the rate at which it is liberated, just as the success of the merchant depends primarily upon his stock of goods and the rapidity of sales. In both cases the stock of any commodity must be increased or renewed whenever the supply of such commodity becomes so depleted as to limit the success of the business, whether on the farm or in the store.

As the organic matter decays, certain decomposition products are formed, including much carbonic acid, some nitric acid, and various organic acids, and these have power to act upon the soil and dissolve the essential mineral plant foods, thus furnishing soluble phosphates, nitrates, and other salts of potassium, magnesium, calcium, etc., for the use of the growing crop.

As already explained, fresh organic matter decomposes much more rapidly than the old humus, which represents the organic residues most resistant to decay and which consequently has accumulated in the soil during the past centuries. The decay of this old humus can be hastened both by tillage, which maintains a porous condition and thus permits the oxygen of the air to enter the soil more freely and to effect the more rapid oxidation of the organic matter, and also by incorporating with the old, resistant residues some fresh organic matter, such as farm manure, clover roots, etc., which decay rapidly and thus furnish or liberate organic matter and inorganic food for bacteria, the bacteria, under such favorable conditions, appearing to have power to attack and decompose the old humus. It is probably for this reason that peat, a very inactive and inefficient fertilizer when used by itself, becomes much more effective when incorporated with fresh farm manure; so that, when used together, two tons of the mixture may be worth as much as two tons of manure, but if applied separately, the peat has little value. Bacterial action is also promoted by the presence of limestone.

The condition of the organic matter of the soil is indicated more or less definitely by the ratio of carbon to nitrogen. As an average, the fresh organic matter incorporated with soils contains about twenty times as much carbon as nitrogen, but the carbohydrates ferment and decompose much more rapidly than the nitrogenous matter; and the old resistant organic residues, such as are found in normal subsoils, commonly contain only five or six times as much carbon as nitrogen. Soils of normal physical composition, such as loam, clay loam, silt loam, and fine sandy loam, when in good productive

condition, contain about twelve to fourteen times as much carbon as nitrogen in the surface soil; while in old, worn soils that are greatly in need of fresh, active, organic manures, the ratio is narrower, sometimes falling below ten of carbon to one of nitrogen. (Except in newly made alluvial soils, the ratio is usually narrower in the subsurface and subsoil than in the surface stratum.)

It should be kept in mind that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all agricultural plants, only one (hydrogen) from water, and seven from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes), in case the amount liberated from the soil is insufficient; but even these plants (which include only the clovers, peas, beans, and vetches, among our common agricultural plants) secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron and sulfur), and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Plants are made of plant-food elements in just the same sense that a building is made of wood and iron, brick, stone, and mortar. Without materials, nothing material can be made. The normal temperature, sunshine, rainfall, and length of season in central Illinois are sufficient to produce 50 bushels of wheat per acre, 100 bushels of corn, 100 bushels of oats, and 4 tons of clover hay; and, where the land is properly drained and properly tilled, such crops would frequently be secured *if the plant foods were present in sufficient amounts and liberated at a sufficiently rapid rate to meet the absolute needs of the crops.*

Crop Requirements

The accompanying table shows the requirements of such crops for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally in sufficient abundance compared with the amounts needed by plants, so that they are not known ever to limit the yield of general farm crops grown under normal conditions.)

Table A.—Plant Food in Wheat, Corn, Oats, and Clover

Produce		Nitrogen, pounds	Phosphorus, pounds	Potassium, pounds	Magnesium, pounds	Calcium, pounds
Kind	Amount					
Wheat, grain	50 bu.	71	12	13	4	1
Wheat straw	2½ tons	25	4	45	4	10
Corn, grain	100 bu.	100	17	19	7	1
Corn stover	3 tons	48	6	52	10	21
Corn cobs	½ ton	2		2		
Oats, grain	100 bu.	66	11	16	4	2
Oat straw	2½ tons	31	5	52	7	15
Clover seed	4 bu.	7	2	3	1	1
Clover hay	4 tons	160	20	120	31	117
Total in grain and seed		244[1]	42	51	16	4
Total in four crops		510[1]	77	322	68	168

[1]These amounts include the nitrogen contained in the clover seed or hay, which, however, may be secured from the air.

To be sure, these are large yields, but shall we try to make possible the production of yields only half or a quarter as large as these, or shall we set as our ideal this higher mark, and then approach it as nearly as possible with profit? Among the four crops, corn is the largest, with a total yield of more than six tons per acre; and yet the 100-bushel crop of corn is often produced on rich pieces of land in good seasons. In very practical and profitable systems of farming, the Illinois Experiment Station has produced, as an average of the six years 1905 to 1910, a yield of 87 bushels of corn per acre in grain farming (with limestone and phosphorus applied, and with crop residues and legume crops turned under), and 90 bushels per acre in live-stock farming (with limestone, phosphorus, and manure).

The importance of maintaining a rich surface soil cannot be too strongly emphasized. This is well illustrated by data from the Rothamsted Experiment Station, the oldest in the world. Thus on Broadbalk field, where wheat has been grown since 1844, the average yields for the ten years 1892 to 1901 were 12.3 bushels per acre on Plot 3 (unfertilized) and 31.8 bushels on Plot 7 (well fertilized), but the amounts of both nitrogen and phosphorus in the subsoil (9 to 27 inches) were distinctly greater in Plot 3 than in Plot 7, thus showing that the higher yields from Plot 7 were due to the fact that the plowed soil had been enriched. In 1893 Plot 7 contained per acre in the surface soil (0 to 9 inches) about 600 pounds more nitrogen and 900 pounds more phosphorus than Plot 3. Even a rich subsoil has little value if it lies beneath a worn-out surface.

Methods of Liberating Plant Food

Limestone and decaying organic matter are the principal materials the farmer can utilize most profitably to bring about the liberation of plant food.

The limestone corrects the acidity of the soil and thus encourages the development not only of the nitrogen-gathering bacteria which live in the nodules on the roots of clover, cowpeas, and other legumes, but also the nitrifying bacteria, which have power to transform the insoluble and unavailable organic nitrogen into soluble and available nitrate nitrogen.

At the same time, the products of this decomposition have power to dissolve the minerals contained in the soil, such as potassium and magnesium, and also to dissolve the insoluble phosphate and limestone which may be applied in low-priced forms.

Tillage, or cultivation, also hastens the liberation of plant food by permitting the air to enter the soil and burn out the organic matter; but it should never be forgotten that tillage is wholly destructive, that it adds nothing whatever to the soil, but always leaves the soil poorer. Tillage should be practiced so far as is necessary to prepare a suitable seed-bed for root development and also for the purpose of killing weeds, but more than this is unnecessary and unprofitable in seasons of normal rainfall; and it is much better actually to enrich the soil by proper applications or additions, including limestone and organic matter (both of which have power to improve the physical condition as well as to liberate plant food) than merely to hasten soil depletion by means of excessive cultivation.

Permanent Soil Improvement

The best and most profitable methods for the permanent improvement of the common soils of Illinois are as follows:

(1) If the soil is acid, apply at least two tons per acre of ground limestone, preferably at times magnesian limestone ($CaCO_3MgCO_3$), which contains both calcium and magnesium and has slightly greater power to correct soil acidity, ton for ton, than the ordinary calcium limestone ($CaCO_3$); and continue to apply about two tons per acre of ground limestone every four or five years. On strongly acid soils, or in preparing the land for alfalfa, five tons per acre of ground limestone may well be used for the first application.

(2) Adopt a good rotation of crops, including a liberal use of legumes, and increase the organic matter of the soil either by plowing under the legume crops and other crop residues (straw and corn stalks), or by using for feed and bedding practically all the crops raised and returning the manure to the land with the least possible loss. No one can say in advance what will prove to be the best rotation of crops, because of variation in farms and farmers, and in prices for produce, but the following are suggested to serve as models or outlines:

First year, corn.
Second year, corn.
Third year, wheat or oats (with clover or clover and grass).
Fourth year, clover or clover and grass.
Fifth year, wheat and clover or grass and clover.
Sixth year, clover or clover and grass.

Of course there should be as many fields as there are years in the rotation. In grain farming, with small grain grown the third and fifth years, most of the coarse products should be returned to the soil, and the clover may be clipped and left on the land (only the clover seed being sold the fourth and sixth years); or, in live-stock farming, the field may be used three years for timothy and clover pasture and meadow if desired. The system may be reduced to a five-year rotation by cutting out either the second or the sixth year, and to a four-year system by omitting the fifth and sixth years.

With two years of corn, followed by oats with clover-seeding the third year, and by clover the fourth year, all produce can be used for feed and bedding if other land is available for permanent pasture. Alfalfa may be grown on a fifth field for four or eight years, which is to be alternated with one of the four; or the alfalfa may be moved every five years, and thus rotated over all five fields every twenty-five years.

Other four-year rotations more suitable for grain farming are:

Wheat (and clover), corn, oats, and clover; or corn (and clover), cowpeas, wheat, and clover. (Alfalfa may be grown on a fifth field and rotated every five years, the hay being sold.)

Good three-year rotations are:

Corn, oats, and clover; corn, wheat, and clover; or wheat (and clover), corn (and clover), and cowpeas, in which two cover crops and one regular crop of legumes are grown in three years.

A five-year rotation of (1) corn (and clover), (2) cowpeas, (3) wheat, (4) clover, and (5) wheat (and clover) allows legumes to be seeded four times, and alfalfa may be grown on a sixth field for five or six years in the combination rotation, alternating between two fields every five years, or rotating over all the fields if moved every six years.

To avoid clover sickness it may sometimes be necessary to substitute sweet clover or alsike for red clover in about every third rotation, and at the same

time to discontinue its use in the cover-crop mixture. If the corn crop is not too rank, cowpeas or soybeans may also be used as a cover crop (seeded at the last cultivation) in the southern part of the state, and, if necessary to avoid disease, these may well alternate in successive rotations.

For easy figuring it may well be kept in mind that the following amounts of nitrogen are required for the produce named:

1 bushel of oats (grain and straw) requires 1 pound of nitrogen.
1 bushel of corn (grain and stalks) requires 1½ pounds of nitrogen.
1 bushel of wheat (grain and straw) requires 2 pounds of nitrogen.
1 ton of timothy requires 24 pounds of nitrogen.
1 ton of clover contains 40 pounds of nitrogen.
1 ton of cowpeas contains 43 pounds of nitrogen.
1 ton of average manure contains 10 pounds of nitrogen.

The roots of clover contain about half as much nitrogen as the tops, and the roots of cowpeas contain about one-tenth as much as the tops.

Soils of moderate productive power will furnish as much nitrogen to clover (and two or three times as much to cowpeas) as will be left in the roots and stubble. For grain crops, such as wheat, corn, and oats, about two-thirds of the nitrogen is contained in the grain and one-third in the straw or stalks. (See also discussion of "The Potassium Problem," on pages below.)

(3) On all lands deficient in phosphorus (except on those susceptible to serious erosion by surface washing or gullying) apply that element in considerably larger amounts than are required to meet the actual needs of the crops desired to be produced. The abundant information thus far secured shows positively that fine-ground natural rock phosphate can be used successfully and very profitably, and clearly indicates that this material will be the most economical form of phosphorus to use in all ordinary systems of permanent, profitable soil improvement. The first application may well be one ton per acre, and subsequently about one-half ton per acre every four or five years should be applied, at least until the phosphorus content of the plowed soil reaches 2,000 pounds per acre, which may require a total application of from three to five or six tons per acre of raw phosphate containing 12½ percent of the element phosphorus.

Steamed bone meal and even acid phosphate may be used in emergencies, but it should always be kept in mind that phosphorus delivered in Illinois costs about 3 cents a pound in raw phosphate (direct from the mine in carload lots), but 10 cents a pound in steamed bone meal, and about 12 cents a pound in acid phosphate, both of which cost too much per ton to permit their common purchase by farmers in carload lots, which is not the case with limestone or raw phosphate.

Phosphorus once applied to the soil remains in it until removed in crops, unless carried away mechanically by soil erosion. (The loss by leaching is only about 1½ pounds per acre per annum, so that more than 150 years would be required to leach away the phosphorus applied in one ton of raw phosphate.)

The phosphate and limestone may be applied at any time during the rotation, but a good method is to apply the limestone after plowing and work it into the surface soil in preparing the seed bed for wheat, oats, rye, or barley, where clover is to be seeded; while phosphate is best plowed under with farm manure, clover, or other green manures, which serve to liberate the phosphorus.

(4) Until the supply of decaying organic matter has been made adequate, on the poorer types of upland timber and gray prairie soils some temporary benefit may be derived from the use of a soluble salt or mixture of salts, such as kainit, which contains both potassium and magnesium in soluble form and also some common salt (sodium chlorid). About 600 pounds per acre of kainit applied and turned under with the raw phosphate will help to dissolve the phosphorus as well as to furnish available potassium and magnesium, and for a few years such use of kainit will no doubt be profitable on lands deficient in organic matter, but the evidence thus far secured indicates that its use is not absolutely necessary and that it will not be profitable after adequate provision is made for decaying organic matter, since this will necessitate returning to the soil either all produce except the grain (in grain farming) or the manure produced in live-stock farming. (Where hay or straw is sold, manure should be bought.)

On soils which are subject to surface washing, including especially the yellow silt loam of the upland timber area, and to some extent the yellow-gray silt loam, and other more rolling areas, the supply of minerals in the subsurface and subsoil (which gradually renew the surface soil) tends to provide for a low-grade system of permanent agriculture if some use is made of legume plants, as in long rotations with much pasture, because both the minerals and nitrogen are thus provided in some amount almost permanently; but where such lands are farmed under such a system, not more than two or three grain crops should be grown during a period of ten or twelve years, the land being kept in pasture most of the time; and where the soil is acid a liberal use of limestone, as top-dressings if necessary, and occasional reseeding with clovers will benefit both the pasture and indirectly the grain crops.

Advantage of Crop Rotation and Permanent Systems

It should be noted that clover is not likely to be well infected with the clover bacteria during the first rotation on a given farm or field where it has not been grown before within recent years; but even a partial stand of clover the first time will probably provide a thousand times as many bacteria for the next clover crop as one could afford to apply in artificial inoculation, for a single root-tubercle may contain a million bacteria developed from one during the season's growth.

This is only one of several advantages of the second course of the rotation over the first course. Thus the mere practice of crop rotation is an advantage, especially in helping to rid the land of insects and foul grass and weeds. The deep-rooting clover crop is an advantage to subsequent crops because of that characteristic. The larger applications of organic manures (made possible by the larger crops) are a great advantage; and in systems of permanent soil improvement, such as are here advised and illustrated, more limestone and more phosphorus are provided than are needed for the meager or moderate crops produced during the first rotation, and consequently the crops in the second rotation have the advantage of such accumulated residues (well incorporated with the plowed soil) in addition to the regular applications made during the second rotation.

This means that these systems tend positively toward the making of richer lands. The ultimate analyses recorded in the tables give the absolute invoice of these Illinois soils. They show that most of them are positively deficient only in limestone, phosphorus, and nitrogenous organic matter: and

the accumulated information from careful and long-continued investigations in different parts of the United States clearly establishes the fact that in general farming these essentials can be supplied with greatest economy and profit by the use of ground natural limestone, very finely ground natural rock phosphate, and legume crops to be plowed under directly or in farm manure. On normal soils no other applications are absolutely necessary, but, as already explained, the addition of some soluble salt in the beginning of a system of improvement on some of these soils produces temporary benefit, and if some inexpensive salt, such as kainit, is used, it may produce sufficient increase to more than pay the added cost.

THE POTASSIUM PROBLEM

As reported in Illinois Bulletin 123, where wheat has been grown every year for more than half a century at Rothamsted, England, exactly the same increase was produced (5.6 bushels per acre), as an average of the first 24 years, whether potassium, magnesium, or sodium was applied, the rate of application per annum being 200 pounds of potassium sulfate and molecular equivalents of magnesium sulfate and sodium sulfate. As an average of 60 years (1852 to 1911), the yield of wheat has been 12.7 bushels on untreated land, 23.3 bushels where 86 pounds of nitrogen and 29 pounds of phosphorus per acre per annum were applied; and, as further additions, 85 pounds of potassium raised the yield to 31.3 bushels; 52 pounds of magnesium raised it to 29.2 bushels; and 50 pounds of sodium raised it to 29.5 bushels. Where potassium was applied, the average wheat crop removed 40 pounds of that element in the grain and straw, or three times as much as would be removed in the grain only for such crops as are suggested in Table A. The Rothamsted soil contained an abundance of limestone, but no organic matter was provided except the little in the stubble and roots of the wheat plants.

On another field at Rothamsted the average yield of barley for 60 years (1852 to 1911) has been 14.2 bushels on untreated land, 38.1 bushels where 43 pounds of nitrogen and 29 pounds of phosphorus have been applied per acre per annum; while the further addition of 85 pounds of potassium, 19 pounds of magnesium, and 14 pounds of sodium (all in sulfates) raised the average yield to 41.5 bushels, but, where only 70 pounds of sodium were applied in addition to the nitrogen and phosphorus, the average has been 43.0 bushels. Thus, as an average of 60 years, the use of sodium produced 1.8 bushels less wheat and 1.5 bushels more barley than the use of potassium, with both grain and straw removed and no organic manures returned.

In recent years the effect of potassium is becoming much more marked than that of sodium or magnesium, on the wheat crop; but this must be expected to occur in time where no potassium is returned in straw or manure, and no provision made for liberating potassium from the supply still remaining in the soil. If more than three-fourths of the potassium removed were returned in the straw (see Table A), and if the decomposition products of the straw have power to liberate additional amounts of potassium from the soil, the necessity of purchasing potassium in a good system of farming on such land is very remote.

While about half the potassium, nitrogen, and organic matter, and about one-fourth the phosphorus contained in manure will be lost by three or four months' exposure in the ordinary pile in the barn yard, there

is practically no loss if plenty of absorbent bedding is used on cement floors, and if the manure is hauled to the field and spread within a day or two after it is produced. Again, while the animals destroy two-thirds of the organic matter and retain one-fourth of the nitrogen and phosphorus in average live-stock farming, they retain less than one-tenth of the potassium, from the food consumed; so that the actual loss of potassium in the products sold from the farm, either in grain farming or in live-stock farming, is wholly negligible on land containing 25,000 pounds or more of potassium in the surface 6⅔ inches.

The removal of one inch of soil per century by surface washing (which is likely to occur wherever there is satisfactory surface drainage and frequent cultivation) would permanently maintain the potassium in grain farming by renewal from the subsoil, provided one-third of the potassium is removed by cropping before the soil is carried away.

From all of these facts it will be seen that the potassium problem is not one of addition but of liberation; and the Rothamsted records show that for many years other soluble salts have practically the same power as potassium to increase crop yields in the absence of sufficient decaying organic matter. Whether this action relates to supplying or liberating potassium for its own sake, or to the power of the soluble salt to increase the availability of phosphorus or other elements, is not known, but where much potassium is removed, as in the entire crops at Rothamsted, with no return of organic residues, probably the soluble salt functions in both ways.

As an average of 112 separate tests conducted in 1907, 1908, 1909, and 1910 on the Fairfield experiment field, an application of 200 pounds of potassium sulfate, containing 85 pounds of potassium and costing $5.10, increased the yield of corn by 9.3 bushels per acre; while 600 pounds of kainit, containing only 60 pounds of potassium and costing $4.00, gave an increase of 10.7 bushels. Thus, at 40 cents a bushel for corn, the kainit has paid for itself; but these results, like those at Rothamsted, were secured where no adequate provision had been made for decaying organic matter.

Additional experiments at Fairfield include an equally complete test with potassium sulfate and kainit on land to which 8 tons per acre of farm manure had been applied. As an average of 112 tests with each material, the 200 pounds of potassium sulfate increased the yield of corn by 1.7 bushels, while the 600 pounds of kainit also gave an increase of 1.7 bushels. Thus, where organic manure was supplied, very little effect was produced by the addition of either potassium sulfate or kainit; in part perhaps because the potassium removed in the crops is mostly returned in the manure if properly cared for, and perhaps in larger part because the decaying organic matter helps to liberate and hold in solution other plant-food elements, especially phosphorus.

In laboratory experiments at the Illinois Experiment Station, it has been shown that potassium salts and most other soluble salts increase the solubility of the phosphorus in soil and in rock phosphate as determined by chemical analysis; also that the addition of glucose with rock phosphate in pot-culture experiments increases the availability of the phosphorus, as measured by plant growth, altho the glucose consists only of carbon, hydrogen, and oxygen, and thus contains no plant food of value.

If we remember that, as an average, live stock destroy two-thirds of the organic matter of the food consumed, it is easy to determine from Table A

that more organic matter will be supplied in a proper grain system than in a strictly live-stock system; and the evidence thus far secured from older experiments at the University and at other places in the state indicates that if the corn stalks, straw, clover, etc., are incorporated with the soil as soon as practicable after they are produced (which can usually be done in the late fall or early spring), there is little or no difficulty in securing sufficient decomposition in our humid climate to avoid serious interference with the capillary movement of the soil moisture, a common danger from plowing under too much coarse manure of any kind in the late spring of a dry year.

If, however, the entire produce of the land is sold from the farm, as in hay farming, or when both grain and straw are sold, of course the draft on potassium will then be so great that in time it must be renewed by some sort of application. As a rule, such farmers ought to secure manure from town, since they furnish the bulk of the material out of which manure is produced.

CALCIUM AND MAGNESIUM

When measured by the actual crop requirements for plant food, magnesium and calcium are more limited in some Illinois soils than potassium. But with these elements we must also consider the loss by leaching. As an average of 90 analyses[1] of Illinois well-waters drawn chiefly from glacial sands, gravels, or till, 3 million pounds of water (about the average annual drainage per acre for Illinois) contained 11 pounds of potassium, 130 of magnesium, and 330 of calcium. These figures are very significant, and it may be stated that if the plowed soil is well supplied with the carbonates of magnesium and calcium, then a very considerable proportion of these amounts will be leached from that stratum. Thus the loss of calcium from the plowed soil of an acre at Rothamsted, England, where the soil contains plenty of limestone, has averaged more than 300 pounds a year as determined by analyzing the soil in 1865 and again in 1905. And practically the same amount of calcium was found by analyzing the Rothamsted drainage waters.

Common limestone, which is calcium carbonate ($CaCO_3$), contains, when pure, 40 percent of calcium, so that 800 pounds of limestone are equivalent to 320 pounds of calcium. Where 10 tons per acre of ground limestone were applied at Edgewood, Illinois, the average annual loss during the next ten years amounted to 790 pounds per acre. The definite data from careful investigations seem to be ample to justify the conclusion that where limestone is needed at least 2 tons per acre should be applied every 4 or 5 years.

It is of interest to note that thirty crops of clover of four tons each would require 3,510 pounds of calcium, while the most common prairie land of southern Illinois contains only 3,420 pounds of total calcium in the plowed soil of an acre. (See Soil Report No. 1.) Thus limestone has a positive value on some soils for the plant food which it supplies, in addition to its value in correcting soil acidity and in improving the physical condition of the soil. Ordinary limestone (abundant in the southern and western parts of the state) contains nearly 800 pounds of calcium per ton; while a good grade of dolomitic limestone (the more common limestone of northern Illinois) contains about 400 pounds of calcium and 300 pounds of magnesium per ton. Both of these elements are furnished in readily available form in ground dolomitic limestone.

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[1]Reported by Doctor Bartow and associates, of the Illinois State Water Survey.

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

SOIL REPORT NO. 8

BOND COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER,
J. H. PETTIT, and O. S. FISHER

URBANA, ILLINOIS, OCTOBER, 1913

INTRODUCTORY NOTE

About two-thirds of Illinois lies in the corn belt, where most of the prairie lands are black or dark brown in color. In the southern third of the state, the prairie soils are largely of a gray color. This region is better known as the wheat belt, altho wheat is often grown in the corn belt and corn is also a common crop in the wheat belt.

Moultrie county, representing the corn belt; Clay county, which is fairly representative of the wheat belt; and Hardin county, which is taken to represent the unglaciated area of the extreme southern part of the state, were selected for the first Illinois Soil Reports by counties. While these three county soil reports were sent to the Station's entire mailing list within the state, subsequent reports are sent only to those on the mailing list who are residents of the county concerned, and to any one else upon request.

Each county report is intended to be as nearly complete in itself as it is practicable to make it, and, even at the expense of some repetition, each will contain a general discussion of important fundamental principles in order to help the farmer and landowner understand the meaning of the soil fertility invoice for the lands in which he is interested. In Soil Report No. 1, "Clay County Soils," this discussion serves in part as an introduction, while in this and other reports, it will be found in the Appendix; but if necessary it should be read and studied in advance of the report proper.

BOND COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER, J. H. PETTIT, and O. S. FISHER

Bond county is located nominally in the lower Illinois glaciation, but much of the area, especially the northwestern part, extends over the broad transition zone between the lower and the middle divisions of the Illinois glaciation, and for this reason some of the soil types are rather better than the average soils of the same type in southern Illinois.

This zone seems once to have been an extensive morainal region. Altho some moraines still exist as long ridges, most of them have been reduced by erosion to rounded hills, so that only $4\frac{1}{4}$ percent of the county is now covered by such formation. Other hilly lands, formed largely by stream erosion, occupy more than 16 percent of the area.

The topography of the more extensive undulating and level uplands was probably produced very largely by the influence of an ice sheet which once covered this region. Like most of the state, this county was overlain by an ice sheet during what is known as the Glacial period. During that period accumulations of snow and ice in parts of Canada became so great that they pushed southward until a point was reached where the ice melted as rapidly as it advanced. In moving across the country, the ice gathered up all sorts and sizes of stone and earthy materials, including masses of rock, boulders, pebbles, and smaller particles. Some of these materials were carried for hundreds of miles and rubbed against the surface rocks or against each other until ground into powder. When the limit of advance was reached, where the ice largely melted, this material would accumulate in a broad undulating ridge, or moraine. When the ice melted away more rapidly than the glacier advanced, the terminus of the glacier would recede and leave the moraine of glacial drift to mark the outer limit of the ice sheet.

The ice made many advances and with each advance and recession a terminal moraine was formed. These moraines are now seen as broad ridges that vary from one to ten miles in width. Thruout the state these advances and recessions of the ice sheet left a system of terminal moraines (irregularly concentric with Lake Michigan) having generally a steep outer slope while the inner slope is longer and more gradual. (See state map in Bulletin 123.)

The material transported by the glacier varied with the character of the rocks over which it passed. Granites, limestones, sandstones, shales, etc., were mixed and ground up together. This mixture of all kinds of boulders, gravel, sand, silt, and clay is called boulder clay, till, glacial drift, or simply drift. The grinding and denuding power of glaciers is enormous. A mass of ice 100 feet thick exerts a pressure of 40 pounds per square inch, and this ice sheet may have been hundreds of feet in thickness. The materials carried and pushed along in this mass of ice, especially the boulders and pebbles, became powerful agents for grinding and wearing away the surface over which the ice passed.

Ridges and hills were rubbed down, valleys filled, and surface features changed entirely.

As the glacier melted in its final recession, the material carried in the great mass of ice was deposited somewhat uniformly, yet not entirely so, over the intermorainal tracts, leaving extensive areas of level, undulating, or rolling plains.

The depth of glacial drift in Bond county varies from a few feet to more than 200 feet, as shown by borings for wells and mines. A thickness of 204 feet was determined by a boring in Greenville. Leverett's estimate for the average thickness of the drift in the county is 85 feet.

The lower Illinois glaciation is characterized by light-colored soils which are usually strongly acid, whereas in the middle and upper Illinois glaciations the darker colored corn-belt soils predominate.

PHYSIOGRAPHY

The highest point in Bond county, 650 feet, is in section 30, township 7 north, range 2 west, while the lowest, about 430 feet, is in the Kaskaskia bottoms in the southeast corner of the county. This gives a difference in altitude of 220 feet. The following are the altitudes in feet above sea level of some stations and towns: Greenville, 555; Hookdale, 503; Mulberry Grove, 549; Perrion, 517; Pocahontas, 498; Reno, 585; Sorento, 591; Stubblefield, 510; Smithboro, 548; Tamalco, 465; Baden Baden, 495; Old Ripley, 540; Pleasant Mound, 515.

The entire county lies in the drainage basin of the Kaskaskia or Okaw river, the general slope being from north to south. About three-fourths of the area is drained thru Shoal creek and its tributaries and thence into the Kaskaskia, while about one-fourth of the area along the east side is drained directly into the Kaskaskia by means of small tributaries. (Beaver creek is a tributary of Shoal creek.) The large streams of the county have cut valleys varying from 25 to 125 feet below the upland, the deeper ones being in the northern part of the county. These valleys have permitted considerable erosion by the small tributaries, and as a result the upland adjacent to the larger streams is usually cut up into hills and valleys unsuited to ordinary agriculture. Before the land was put under cultivation, forests had advanced up the streams and were slowly invading the prairies, thus producing a belt of timber soil along the streams.

SOIL MATERIAL AND SOIL TYPES

The Illinois glacier covered Bond county and left a thick mantle of drift, completely burying the old soil that preceded it. Then a long period elapsed, during which a soil known as the old Sangamon soil was formed on the surface of this drift. Later other ice invasions occurred, but they covered only the northern part of the state. (See state map in Bulletin 123, Iowan and Wisconsin glaciations.)

These later ice sheets did not reach Bond county, but finely ground rock (rock flour) in immense quantities was carried south by the waters from the melting ice and deposited on the flooded plains, where, when dry, it was picked up by the wind, carried farther, and finally deposited on the surface, burying the old Sangamon soil[1] to a depth of 5 to 20 feet or more. This wind-blown material,

[1]The Sangamon soil may sometimes be seen in cuts as a somewhat dark or bluish sticky clay or a weathered zone of yellowish or brownish clay.

called loess, is a mixture of all kinds of material over which the glacier passed. It may be recognized as a yellow, fine-grained material naturally free from glacial pebbles, usually underlain by the pebble-bearing drift.

After the loessal material was deposited over the country, the surface stratum became mixed with more or less organic matter and thus was gradually changed into soil. Surface washing has produced other changes.

The soils of Bond county are divided into the four following classes:

(1) Upland prairie soils. These were originally covered with wild prairie grasses, the partially decayed roots of which have been the chief source of the organic matter. The flat prairie land, naturally poorly drained, contains the higher amount of organic matter because the grasses and roots grew more luxuriantly there and were largely preserved from decay by the higher moisture content of the soil.

(2) Upland timber soils, including those zones along stream courses over which forests once extended. These soils contain less organic matter than the upland prairie soils, because the large roots of dead trees and the surface accumulations of leaves, twigs, and fallen trees were burned by forest fires or suffered almost complete decay. The timber lands may be divided roughly into three classes: the level, the undulating, and the hilly areas.

(3) Ridge soils, including those on morainal ridges, most of which have been forested. They may be divided into pervious and tight (almost impervious). The former class includes some of the best soils of the county, while the soils of the latter class are among the poorest.

(4) Bottom-land soils, including the flood plains along streams.

TABLE 1.—SOIL TYPES OF BOND COUNTY

Soil type No.	Name of type	Area in square miles	Area in acres	Percent of total area
	(a) Upland Prairie Soils (page 24)			
330	Gray silt loam on tight clay	121.49	77 754	32.66
328	Brown-gray silt loam on tight clay	61.49	39 354	16.54
329	Drab silt loam	2.46	1 574	.66
331	Deep gray silt loam	2.19	1 401	.59
325.1	Black silt loam on clay	2.48	1 587	.67
	(b) Upland Timber Soils (page 33)			
334	Yellow-gray silt loam	48.76	31 206	13.13
335	Yellow silt loam	60.09	38 458	16.15
332	Light gray silt loam on tight clay	16.45	10 528	4.42
332.1	White silt loam on tight clay	.68	435	.18
	(c) Ridge Soils (page 42)			
235	Yellow silt loam	12.41	7 942	3.33
233	Gray-red silt loam on tight clay	1.44	922	.39
245	Yellow fine sandy silt loam	1.98	1 267	.53
	(d) Bottom-Land Soils (page 44)			
1331	Deep gray silt loam	26.22	16 781	7.05
1326	Deep brown silt loam	13.74	8 794	3.70
	Total	371.88	238 003	100.00

Table 1 shows the area of each type of soil in the county, and its percentage of the total area. The accompanying map shows the location and boundary lines of every type of soil in the county, even down to areas of a few acres; and in

Table 2 are reported the amounts of organic carbon (the best measure of the organic matter) and the total amounts of the five important elements of plant food contained in 2 million pounds of the surface soil of each type (the plowed soil of an acre about 6⅔ inches deep). In addition, the table shows the amount of limestone present, if any, or the soil acidity as measured by the amount of limestone required to neutralize the acidity existing in the soil.[1]

THE INVOICE AND INCREASE OF FERTILITY IN BOND COUNTY SOILS

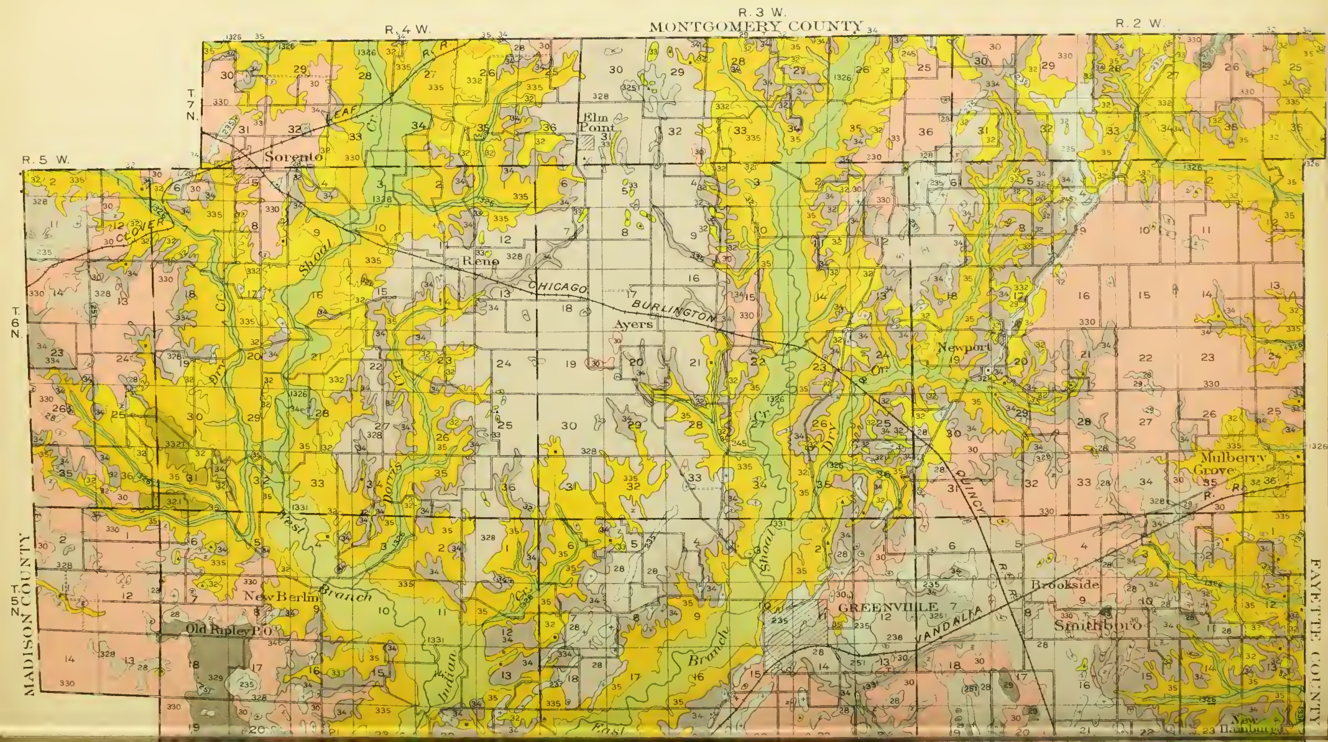
Soil Analysis

In order to avoid confusion in applying in a practical way the technical information contained in this report, the results are given in the most simplified form. The composition reported for a given soil type is, as a rule, the average of many analyses, which, like most things in nature, show more or less variation; but for all practical purposes the average is most trustworthy and sufficient. (See Bulletin 123, which reports the general soil survey of the state, together with many hundred individual analyses of soil samples representing twenty-five of the most important and most extensive soil types in the state.)

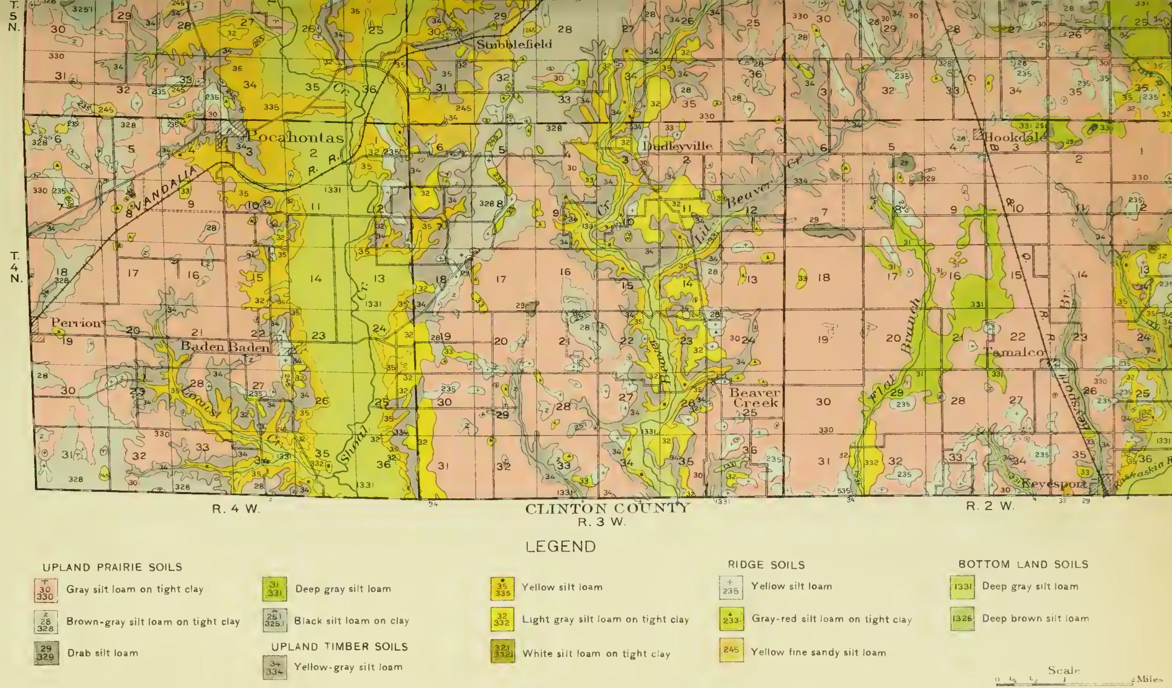
The chemical analysis of a soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but, as explained in the Appendix, the rate of liberation is governed by many factors. Also, as there stated, probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that the productive power of normal soil in humid sections depends upon the stock of plant food contained in the soil and upon the rate at which it is liberated.

The fact may be repeated, too, that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all plants, only one (hydrogen) from water, while seven are secured from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes) in case the amount liberated from the soil is insufficient. But even the leguminous plants (which include the clovers, peas, beans, alfalfa, and vetches), in common with other agricultural plants, secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron, and sulfur) and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

[1]The figures given in Table 2 (and in the corresponding tables for subsurface and subsoil) are the averages for all determinations, with some exceptions of limestone or acidity present. Some soil types, particularly those which are subject to erosion, may vary from acid to alkaline, especially in the subsurface or subsoil; and in such cases abnormal results are discarded, a report of the normal conditions being more useful than any average of figures involving both plus and minus quantities.



MONTGOMERY COUNTY
MADISON COUNTY
FAYETTE COUNTY
R. 5 W.
R. 4 W.
R. 3 W.
R. 2 W.
T. 7 N.
T. 6 N.
T. 5 N.
Sorento
Elm Point
Reno
Ayers
Newport
Mulberry Grove
Brookside
Smithboro
GREENVILLE
New Berlin
Old Ripley P.O.
New Hamburg
CHICAGO BURLINGTON & QUINCY R. R.
VANDALIA R. R.
CLOVER LEAF R. R.
Shoal Cr.
Dry Cr.
Dorris Cr.
East Fork
West Branch
Indian Branch
Shoal Branch



SOIL SURVEY MAP OF BOND COUNTY

UNIVERSITY OF ILLINOIS AGRICULTURAL EXPERIMENT STATION

Table A in the Appendix shows the requirements of large crops for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally from natural sources in sufficient abundance, compared with the amounts needed by plants, so that they are never known to limit the yield of common farm crops.)

As already stated, the data in Table 2 represent the total amounts of plant-food elements found in 2 million pounds of surface soil in Bond county, which corresponds to an acre about 6⅔ inches deep. This includes at least as much soil as is ordinarily turned with the plow, and represents that part with which the farm manure, limestone, phosphate, or other fertilizer applied in soil improvement is incorporated. It is the soil stratum that must be depended upon in large part to furnish the necessary plant food for the production of crops, as will be seen from the information given in the Appendix. Even a rich subsoil has little or no value if it lies beneath a worn-out surface, for the weak, shallow-rooted plants will be unable to reach the supply of plant food in the subsoil. If, however, the fertility of the surface soil is maintained at a high point, then the plants, with a vigorous start from the rich surface soil, can draw upon the subsurface and subsoil for a greater supply of plant food.

By easy computation it will be found that the most common prairie soils of Bond county do not contain in the plowed soil more than enough total nitrogen for the production of maximum crops for twenty-two years; while the upland timber soils contain, as an average, even less nitrogen than the prairie land.

With respect to phosphorus, the condition differs only in degree, nearly nine-tenths of the soil area of the county containing no more of that element than would be required for ten crop rotations if such yields were secured as are

TABLE 2.—FERTILITY IN THE SOILS OF BOND COUNTY
Average pounds per acre in 2 million pounds of surface soil (about 0 to 6⅔ inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity present
	Upland Prairie Soils								
330	Gray silt loam on tight clay............	25 620	2 640	770	27 410	4 710	5 200		560
328	Brown-gray silt loam on tight clay............	29 490	2 840	670	31 040	4 590	6 210		100
329	Drab silt loam.........	36 400	3 640	720	29 780	6 320	7 500		120
331	Deep gray silt loam....	29 460	2 840	680	24 180	3 780	4 040		960
325.1	Black silt loam on clay.	56 540	4 760	1 020	32 540	9 820	15 540		20
	Upland Timber Soils								
334	Yellow-gray silt loam..	26 440	2 530	470	35 500	5 870	5 320		320
335	Yellow silt loam.......	22 110	2 068	696	36 024	6 444	5 040		940
332	Light gray silt loam on tight clay............	18 780	1 760	740	26 980	4 720	4 110		280
332.1	White silt loam on tight clay	14 860	1 360	660	30 120	4 380	5 400		1 400
	Ridge Soils								
235	Yellow silt loam.......	21 340	1 940	740	38 940	5 400	8 240		20
233	Gray-red silt loam on tight clay............	35 700	3 600	820	25 600	7 140	6 580		400
245	Yellow fine sandy silt loam	23 120	2 650	720	39 040	5 700	9 850		30
	Bottom-Land Soils								
1331	Deep gray silt loam....	33 200	3 120	1 640	37 240	9 160	7 380		80
1326	Deep brown silt loam..	23 420	2 100	1 100	34 480	7 080	9 760		20

suggested in Table A of the Appendix. It will be seen from the same table that in the case of the cereals about three-fourths of the phosphorus taken from the soil is deposited in the grain, while only one-fourth remains in the straw or stalks.

On the other hand, the potassium is sufficient for 20 centuries if only the grain is sold, or for 300 years even if the total crops should be removed and nothing returned. The corresponding figures are about 1,200 and 300 years for magnesium, and about 5,000 and 120 years for calcium. Thus, when measured by the actual crop requirements for plant food, potassium is no more limited than magnesium and calcium, and, as explained in the Appendix, with these elements we must also consider the fact that loss by leaching is far greater than by cropping.

These general statements relating to the total quantities of plant food in the plowed soil certainly emphasize the fact that the supplies of some of these necessary elements of fertility are extremely limited when measured by the needs of large crop yields for even one or two generations of people.

The variation among the different types of soil in Bond county with respect to their content of important plant-food elements is also very marked. Thus, the richest prairie land (black silt loam on clay) contains about twice as much phosphorus and nitrogen as the common upland timber soils; and the bottom lands are still richer in phosphorus. The most significant facts revealed by the investigation of the Bond county soils are the lack of limestone and the low phosphorus content of the common upland types, which cover nearly 90 percent of the entire county. And yet both of these deficiencies can be overcome at a relatively small expense by the application of ground limestone and fine-ground raw rock phosphate; and, after these are provided, clover can be grown and nitrogen thus secured from the inexhaustible supply in the air. If the clover were then returned to the soil, either directly or in farm manure, the combined effect of limestone, phosphorus, and nitrogenous organic matter, with a good rotation of crops, would in time double or treble the yield of wheat, corn, and other crops, on most farms.

Until the supply of decaying organic matter has been made adequate, some temporary benefit may be derived from the use of a soluble salt or a mixture of salts, such as kainit, which contains both potassium and magnesium in soluble form and also some common salt (sodium chlorid). About 600 pounds per acre of kainit applied and turned under with the raw phosphate will help to dissolve the phosphorus as well as furnish available potassium and magnesium, and for a few years such use of kainit may be profitable on lands deficient in organic matter. The evidence thus far secured, however, indicates that its use is not absolutely necessary and that it will not be profitable after adequate provision is made for decaying organic matter, which contains some potassium and liberates additional supplies from the soil.

Fortunately, some definite field experiments have already been conducted on some of these most extensive types of soil in the lower Illinois glaciation, as at DuBois in Washington county, at Fairfield in Wayne county, and at Raleigh in Saline county. Before considering in detail the individual soil types, it seems advisable to study some of the results already obtained where definite systems of soil improvement have been tried out on some of these experiment fields in different parts of southern Illinois.

RESULTS OF FIELD EXPERIMENTS AT DUBOIS

In Tables 3 and 4 are recorded some exceedingly valuable and instructive data. These results have been secured by twelve years of actual trial on the most common type of soil in Bond county, gray silt loam on tight clay, which is also a very common type in Washington county, where the DuBois experiment field is located.

TABLE 3.—CROP YIELDS IN SOIL EXPERIMENTS, DUBOIS FIELD: NOT TILE-DRAINED

Gray silt loam on tight clay; lower Illinois glaciation		Corn 1902	Oats 1903	Wheat 1904	Clover 1905	Corn 1906	Oats 1907	Wheat 1908	Soy-beans 1909	Corn 1910	Oats 1911	Clover 1912[1]	Wheat 1913
Plot	Soil treatment applied	Bushels or tons per acre											
101	None	6.4	9.4	6.3	1.25	30.3	18.8	.8	3.5	25.8	13.1	.46	7.7
102	Lime	6.7	16.2	6.5	1.57	35.2	28.8	8.0	6.7	26.2	24.1	40	8.7
103	Lime, crop res.	5.9	18.1	11.0	1.78	38.0	38.1	8.5	7.2	33.6	31.9	(.92)	14.7
104	Lime, phos.	13.4	25.9	25.0	2.42	38.7	43.8	17.8	8.5	17.6	40.9	1.02	21.0
105	Lime, potas.	11.6	27.5	16.2	2.22	48.8	37.2	14.8	9.3	65.6	29.1	.81	16.8
106	Lime, res., phos.	9.3	25.0	32.7	2.30	32.3	46.6	19.8	8.2	30.0	35.9	(2.42)	29.7
107	Lime, res., potas.	6.8	23.8	20.2	2.34	43.6	43.8	16.5	7.8	67.6	29.1	(3.92)	21.0
108	Lime, phos., potas.	12.4	30.0	27.5	2.86	48.9	50.0	20.8	9.5	73.2	35.3	1.34	30.2
109	Lime, res., phos., potas.	10.4	29.1	33.3	2.83	46.3	46.6	19.7	7.8	73.2	38.8	(3.00)	30.2
110	Res., phos., potas.	2.0	25.6	27.3	2.59	39.9	36.9	10.0	6.3	66.8	26.6	(1.67)	10.7
	Average Increase: Bushels or Tons per Acre												
	For lime	.3	6.8	.2	.32	4.9	10.0	7.2	3.2	.4	11.0	–.06	1.0
	For residues	–.8	1.9	4.5	.21	2.8	9.3	.5	.5	7.4	7.8	.52	6.0
	For phosphorus	6.7	9.7	18.5	.85	3.5	15.0	9.8	1.8	–8.6	16.8	.62	12.3
	For potassium	4.9	11.3	9.7	.65	13.6	8.4	6.8	2.6	39.4	5.0	.41	8.1
	For res., phos. over phos.	–4.1	–.9	7.7	–.12	–6.4	2.8	2.0	–.3	12.4	–5.0	1.40	8.7
	For phos., res. over res.	3.4	6.9	21.7	.52	–5.7	8.5	11.3	1.0	–3.6	4.0	1.50	15.0
	For potas., res., phos. over res., phos.	1.1	4.1	.6	.53	14.0	0.0	–.1	–.4	43.2	2.9	.58	.5

Value of Crops per Acre in Twelve Years

Plot	Soil treatment applied	Total value of twelve crops	Value of increase
101	None	$58.39	
102	Lime	79.33	$20.94
103	Lime, residues	100.88	42.49
104	Lime, phosphorus	131.37	72.98
105	Lime, potassium	133.18	74.79
106	Lime, residues, phosphorus	151.37	92.98
107	Lime, residues, potassium	156.06	97.67
108	Lime, phosphorus, potassium	171.32	112.93
109	Lime, residues, phosphorus, potassium	180.83	122.44
110	Residues, phosphorus, potassium	130.23	71.84

Value of Increase per Acre in Twelve Years		Cost of increase
For lime	$20.94	$10.00?
For residues	21.55	?
For phosphorus	52.04	30.00
For *residues* and phosphorus over phosphorus	20.00	?
For *phosphorus* and residues over residues	50.48	30.00
For *potassium*, residues, and phosphorus over residues and phosphorus	29.46	30.00

[1] Figures in parentheses indicate bushels of seed; the others, tons of hay.

Has tile drainage been profitable? There are 120 comparisons which bear on the answer to this question, and the average of all these results summarized in terms of value shows that the tile drainage has paid $5.59 per acre in twelve years, or 47 cents per acre for each year; whereas it would require at least $1.20 an acre a year to pay 6 percent interest on the cost of the tile drainage, the lines of tile being laid five rods apart at a cost of not less than $20 per acre.

TABLE 4.—CROP YIELDS IN SOIL EXPERIMENTS, DUBOIS FIELD: TILE-DRAINED

Gray silt loam on tight clay; lower Illinois glaciation		Corn 1902	Oats 1903	Wheat 1904	Clover 1905	Corn 1906	Oats 1907	Wheat 1908	Soybeans 1909	Corn 1910	Oats 1911	Clover 1912[1]	Wheat 1913
Plot	Soil treatment applied	Bushels or tons per acre											
111	None	1.4	17.2	3.3	1.29	32.5	13.1	4.3	3.3	27.4	12.2	.40	6.7
112	Lime	3.3	17.2	11.5	1.72	33.6	23.8	11.0	6.2	29.0	19.4	.66	16.5
113	Lime, crop res.	2.7	20.6	9.2	1.79	31.7	30.0	14.5	6.7	36.6	27.2	(1.83)	21.5
114	Lime, phos.	6.5	27.5	28.3	2.27	29.7	31.9	19.2	7.2	22.2	30.9	.71	22.8
115	Lime, potas.	4.9	27.2	14.7	2.16	47.5	46.3	16.2	7.8	64.2	26.6	.85	21.8
116	Lime, res., phos.	8.0	33.8	31.2	2.44	30.5	45.9	19.5	8.8	39.4	35.6	(2.50)	37.2
117	Lime, res., potas.	7.3	27.2	23.3	2.52	48.3	39.1	18.5	10.2	74.6	32.2	(2.75)	28.8
118	Lime, phos., potas.	14.1	25.6	32.2	2.95	55.2	44.4	23.0	10.3	76.4	33.4	1.31	30.8
119	Lime, res., phos., potas.	10.4	31.9	30.5	2.89	51.6	42.2	21.3	11.3	75.8	38.8	(2.33)	29.5
120	Res., phos., potas.	4.8	33.1	28.2	2.79	50.7	35.3	12.0	6.7	65.4	28.1	(1.83)	24.0

Average Increase: Bushels or Tons per Acre

	Corn 1902	Oats 1903	Wheat 1904	Clover 1905	Corn 1906	Oats 1907	Wheat 1908	Soybeans 1909	Corn 1910	Oats 1911	Clover 1912	Wheat 1913
For lime	1.9	.0	8.2	.43	1.1	10.7	6.7	2.9	1.6	7.2	.26	9.8
For residues	–.6	3.4	–2.3	.07	–1.9	6.2	3.5	.5	7.6	7.8	1.17	5.0
For phosphorus	3.2	10.3	16.8	.55	–3.9	8.1	8.2	1.0	–6.8	11.5	.05	6.3
For potassium	1.6	10.0	3.2	.44	13.9	22.5	5.2	1.6	35.2	7.2	.19	5.2
For res., phos. over phos.	1.5	6.3	2.9	.17	.8	14.0	.3	1.6	17.2	4.7	1.79	14.4
For phos., res. over res.	5.3	13.2	22.0	.65	–1.2	15.9	5.0	2.1	2.8	8.4	.67	15.7
For potas., res., phos. over res., phos.	2.4	–1.9	–.7	.45	21.1	–3.7	1.8	2.5	36.4	3.2	–.17	–7.7

Value of Crops per Acre in Twelve Years

Plot	Soil treatment applied	Total value of twelve crops	Value of increase
111	None	$ 57.66	
112	Lime	88.97	$ 31.31
113	Lime, residues	108.25	50.59
114	Lime, phosphorus	121.82	64.16
115	Lime, potassium	133.59	75.93
116	Lime, residues, phosphorus	161.83	104.17
117	Lime, residues, potassium	166.36	108.70
118	Lime, phosphorus, potassium	178.08	120.42
119	Lime, residues, phosphorus, potassium	181.63	123.97
120	Residues, phosphorus, potassium	150.62	92.96

Value of Increase per Acre in Twelve Years		Cost of increase
For lime	$31.31	$10.00?
For residues	19.28	?
For phosphorus	33.85	30.00
For *residues* and phosphorus over phosphorus	40.01	?
For *phosphorus* and residues over residues	53.58	30.00
For *potassium*, residues, and phosphorus over residues and phosphorus	19.80	30.00

[1] Figures in parentheses indicate bushels of seed; the others tons of hay.

Is the application of lime and phosphorus of benefit on this type of soil? The answer to this question is found in the fact that the value of the twelve crops on the untreated land amounted to only $58.02, whereas the value of the increase produced by lime and phosphorus was $68.58, as an average of the two series. In other words, this treatment has resulted in an increase greater than the crop produced by the unaided land, raising the crop values from $58.02 to $126.60, counting corn at 35 cents a bushel, oats at 30 cents, wheat at 70 cents, hay at $6 a ton, clover seed at $6 a bushel, and soybeans at $1 a bushel—prices that are probably sufficiently below the ten-year average to provide for the expense of application and of harvesting and marketing the increase. It should be stated, too, that the application of lime and phosphorus has produced a marked improvement in the quality of the crops (especially in the wheat and clover), for which credit is not given in these values.

The materials used per acre in these experiments were as follows: 5 tons of slaked burned lime (applied only at the beginning of the experiments), 2400 pounds of steamed bone meal (800 pounds for each four-year rotation), and 1200 pounds of potassium sulfate (400 pounds for each rotation). Other investigations (reported in Circulars 110, 127, 157, 165, and 168) have shown that ground natural limestone and fine-ground natural rock phosphate are more economical and profitable forms of lime and phosphorus, and that the same effect produced by potassium sulfate can also be secured at much less expense either by means of decaying organic matter (from crop residues, green-manure crops, or farm manure), or by the use of less expensive soluble salts, such as kainit, as shown in the Appendix. If ground limestone had been used on the DuBois field, $10 would have paid for the full equivalent of the slaked lime applied, and allowing $30 for the bone meal (its actual cost), we find that the increase produced has paid for the materials and left a net profit of $2.38 per acre per annum, or 70 percent above the cost. As an average of both series, lime alone has paid back $26.12 per acre in twelve years, and phosphorus used in addition to lime and crop residues has paid back $52.03. Furthermore, about one-third of the lime applied and at least two-thirds of the phosphorus applied still remain in the soil for the benefit of future crops.

The potassium (kalium) applied during the twelve years has cost $30, and when applied in addition to lime, phosphorus, and crop residues, it has produced increases valued at $24.63, leaving a loss of 45 cents per acre per annum. Furthermore, the potassium removed is equal to the total amount applied.

On five duplicate plots in the DuBois field commercial nitrogen was used either alone or with other elements during the first three years, but at a large financial loss and with no apparent residual effect. Since 1907, a system has been adopted for these plots which supplies both nitrogen and organic matter by means of crop residues. A study of the detailed results shows an increasing effect from the organic matter thus supplied. The value of the increase produced by the crop residues during the last rotation (four years) was $13.89 per acre where they were used over lime, and $22.79 where they were used over both lime and phosphorus, this representing the average of the two series of plots. The corresponding figures for the gross return from $45 worth of commercial nitrogen used during the first rotation are $2.16 and $4.21.

PLATE 1.—CROP VALUES FOR TWELVE YEARS
DUBOIS EXPERIMENT FIELD; LAND NOT TILE-DRAINED

(L=lime or limestone; R=residues; P=phosphorus; K=potassium, or kalium)

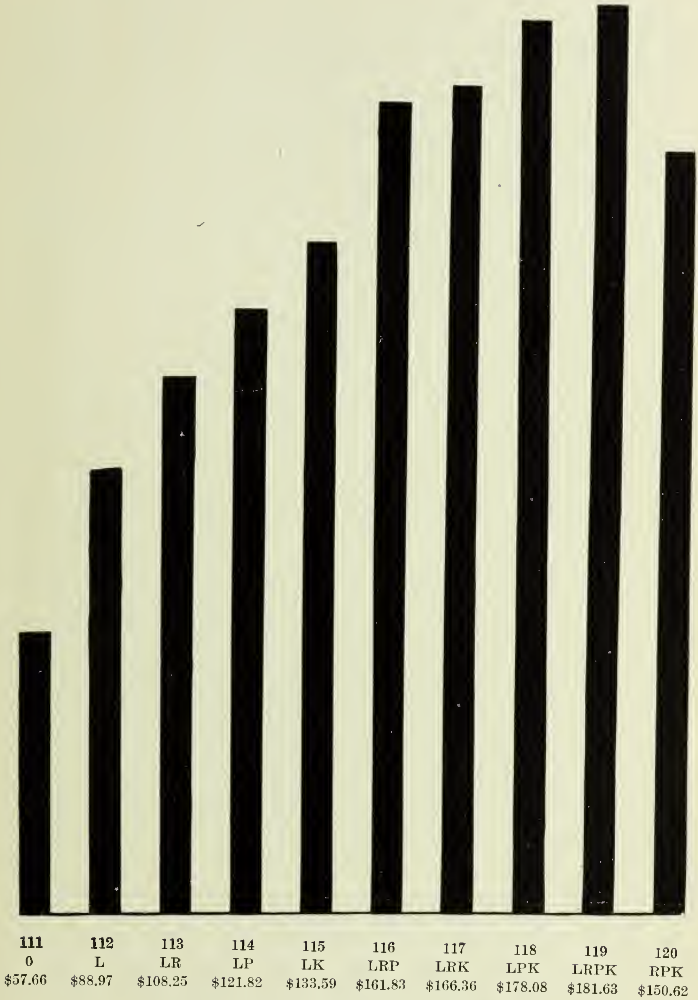


PLATE 2.—CROP VALUES FOR TWELVE YEARS
DUBOIS EXPERIMENT FIELD; LAND TILE-DRAINED

(L=lime or limestone; R=residues; P=phosphorus; K=potassium, or kalium)

It should be kept in mind that the first clover to be plowed under on the DuBois field was in 1912, the system of supplying nitrogen in crop residues having been practiced only since 1907, and the clover having failed in 1908 owing to drouth. The small soybean crop of 1909 furnished but little straw, and the other straw and corn stalks are of slow action, so that final conclusions cannot yet be drawn as to the benefit of crop residues when the system is fully under way. Of course these organic residues are provided not only to furnish nitrogen, but also to aid the liberation of mineral plant food, especially potassium. In this connection a study of the effect of potassium is important.

It is an interesting fact that in aggregate value and on the corn crop, potassium has produced thus far an even larger benefit than phosphorus. Either one of these elements has paid well when used without the other; whereas neither has paid its cost when used in addition to the other.

The soil type of the DuBois field contains in 2 million pounds of surface soil about 800 pounds of phosphorus and 25,000 pounds of potassium. After limestone and organic matter carrying nitrogen have been supplied, phosphorus is the only addition that is absolutely essential for the maintenance of plant food in permanent rational systems of farming.

A summary of the twelve years' results shows, as an average of the two series, a crop value of $58.02 per acre from the unfertilized land, and increased values as follows:

For lime alone	$ 26.12	or	45 percent
For nitrogen and organic matter over lime	20.41	or	24 percent
For phosphorus as a further addition	52.03	or	50 percent
For potassium as a final addition	24.63	or	16 percent
For total increase over untreated land	$123.19	or	212 percent

Thus arranged, the field results are in harmony with what might be expected from the chemical composition of the soil. It should be noted that, of the $24.63 credited to potassium, $13.93, or more than half, is due to its very marked effect upon the corn crop of 1910, when the corn on all potassium plots seemed to possess unusual power of resistance against adverse conditions, including an attack by chinch bugs. The corn crop of 1906 also showed benefit from potassium, $6.14. Thus $20.07, or four-fifths of the benefit, was produced in two of the twelve crops. With the inadequate supply of active organic matter thus far provided, potassium applied without phosphorus seems to have influenced the liberation of phosphorus from the soil itself, so that the benefit of this stimulating action, combined with the possible direct benefit of soluble potassium applied for its own sake, has exceeded temporarily the direct benefit of applied phosphorus. It must be plain, however, that no system can be permanent which does not provide for the application of phosphorus; and that if one desires to make the most rapid progress in the improvement of such soil, he should use limestone, phosphorus, and kainit, until the supply of organic manures becomes sufficient to render the continued use of kainit unprofitable. From the information given in the Appendix, it will be seen that kainit produces greater benefit than potassium sulfate, and at less expense; so that, while potassium sulfate in addition to phosphorus has been used with loss on the DuBois field, if kainit were substituted for sulfate it might add to the total profits, at least until the soil could be well filled with active organic matter from crop residues or farm manure.

The beneficial effect of soluble potassium where no phosphorus has been added, over a period of twelve years, on the DuBois field, and the fact that sodium, an element which has no value as plant food, produced exactly the same increase as potassium over a period of twice twelve years on Broadbalk field at Rothamsted, only support the following statement quoted on page 208 of Bulletin 123, "The Fertility in Illinois Soils":

"In considering the general subject of culture experiments for determining fertilizer needs, emphasis must be laid on the fact that such experiments should never be accepted as the sole guide in determining future agricultural practice. If the culture experiments and the ultimate chemical analysis of the soil agree in the deficiency of any plant-food element, then the information is conclusive and final; but if these two sources of information disagree, then the culture experiments should be considered as tentative and likely to give way with increasing knowledge and improved methods to the information based on chemical analysis, which is absolute.'"[1]

RESULTS OF FIELD EXPERIMENTS AT FAIRFIELD

The Fairfield experiment field is divided into four tracts of ten acres each, and cultivated in a four-year rotation, consisting of corn, cowpeas or soybeans, wheat, and clover. If the clover fails, cowpeas or soybeans may be substituted for that season; if the winter wheat fails, oats may be substituted in the spring.

One half of the field, or twenty acres, is tile-drained, while the other half has only the ordinary surface drainage as commonly provided by plowing in rather narrow lands and keeping the middle furrows open. On both the tiled and the untiled land grain farming is practiced on one half and live-stock farming on the other half. A part of each of these divisions is treated with two tons of limestone and one ton of fine-ground raw rock phosphate, per acre, every four years, while another part is not so treated.

In the system of grain farming, all produce except the grain or seed is returned to the land, while in the live-stock farming all produce (or its equivalent) is used for feed and bedding and the manure returned to the land in proportion to the crop yields produced during the previous rotation. Thus, if the land treated with manure, limestone, and phosphate produces, as an average in one rotation, one-half larger crops than the land which receives manure alone, then one-half more manure is applied to that land for the following rotation. Likewise, in the grain system, the clover and other crop residues returned are in proportion to the yield produced during the rotation on the respective parts of the field. It should be stated that during the first rotation the manure was applied in the same amount (8 tons per acre) on all fields in the live-stock system.

The regular plan is to apply the phosphate and plow it under with manure or other organic matter, and to apply the limestone immediately after the ground is plowed for wheat, in order that the limestone may be mixed with the surface soil in the preparation of the seed-bed where clover is to be seeded the following

[1]Taken from "Culture Experiments for Determining Fertilizer Needs," by C. G. H. in Cyclopedia of American Agriculture, Volume I, page 475.

spring. However, the time and method of application are very secondary matters; the important thing is to get the limestone and phosphate on the land and well mixed with the plowed soil, altho it is better to mix one with the soil before applying the other, because when applied in intimate contact with each other the limestone tends temporarily to lessen the availability of the phosphorus, probably by immediately neutralizing the nitric, carbonic, and organic acids produced in the decay of organic matter.

At $1.25 a ton for limestone and $7.50 a ton for rock phosphate, the cost of those materials for four years amounts to $10 an acre. After three or four rotations, however, the phosphate applications will be reduced to about one-half ton, which will reduce the annual expense to about $1.50 per acre. This expense would be practically covered by an increase of 4 bushels of corn, 1½ bushels of cowpeas or soybeans, 2 bushels of wheat, or ¼ ton of hay, at very moderate prices.

In Tables 5, 6, 7, and 8 are recorded the crop yields obtained since experiments were begun on four different series of plots on the Fairfield field.[1] Only two series were under experiment during the first year (1905), and all the first four years are to be considered as preliminary, in part because of the impossibility of securing the ordinary benefits of a four-year rotation during the first rotation period, in part because during the first four years, in the live-stock system, the manure was applied uniformly regardless of crop yields, and, in particular, because the present plan of returning crop residues was not begun until the end of the first four years, whereas the use of manure was begun the

PLATE 3.—CLOVER ON FAIRFIELD EXPERIMENT FIELD, 1910. (THE FIRST CROP, SHOWN IN PHOTOGRAPHS, WAS CLIPPED AND LEFT ON THE LAND; THE SECOND CROP PRODUCED NO CLOVER SEED ON THE UNTREATED LAND, BUT 1⅕ BUSHELS WERE HARVESTED WHERE THE LIMESTONE AND PHOSPHATE WERE APPLIED WITH NO POTASSIUM SALTS)

[1]Other parts of this experiment field are used for investigations relating to crop production, such as the testing of varieties.

first year (1905) on Series 100, the second year (1906) on Series 400, the third year (1907) on Series 300, and the fourth year (1908) on Series 200.

In the fall and winter of 1905-06 a system of tiling with a good grade and a satisfactory outlet was laid. Four-inch tiles were placed only four rods apart, the two lines on the east half of each series about 20 to 24 inches deep and the two on the west half about 36 to 40 inches deep. Before the ditches were filled, the tile in Series 400 was covered with about 4 inches of gravel, that in Series 300 with 4 inches of cinders, and that in Series 200 with 6 inches of straw. In Series 100 the tile was covered with only the natural dirt. Some of the tiled land of this field is more nearly level than the untiled land, altho the entire field is what would be called level prairie land.

As an average of all results reported in Tables 5, 6, 7, and 8, from these four series of plots, the tile drainage has paid \$9.11 per acre in eight years, or \$1.14 per acre for each year; whereas it would require at least \$1.50 an acre a year to pay 6 percent interest on the cost of the tile drainage, which was not less than \$25 per acre. It may be added, however, that for the last four years the average increased value resulting from tiling has been \$1.80 per acre per year, which would pay a fair rate of interest on the investment if the cost of tiling did not exceed \$30 per acre.

While it is very possible that, with the continued use of clover (the "best subsoiler") in the rotation, the tile drainage may ultimately prove to be a profitable investment, it is plain that the first requisites for the improvement of this soil are limestone, phosphorus, and organic matter.

PLATE 4.—CLOVER ON FAIRFIELD EXPERIMENT FIELD, 1910. (THE FIRST CROP, SHOWN IN PHOTOGRAPH, MADE ⅗ TON OF FOUL GRASS WITH BUT LITTLE CLOVER WHERE MANURE ALONE WAS USED, AND 2⅔ TONS OF CLEAN CLOVER HAY WHERE THE SAME AMOUNT OF MANURE WAS USED WITH LIMESTONE AND PHOSPHATE WITH NO POTASSIUM SALTS)

TABLE 5.—CROP YIELDS IN SOIL EXPERIMENTS, FAIRFIELD FIELD: SERIES 100

Gray silt loam on tight clay; lower Illinois glaciation		Corn 1905	Soy-beans 1906	Wheat 1907	Clover 1908	Corn 1909	Soy-beans 1910	Wheat 1911	Clover[1] 1912	Value 1st 4 years	Value 2d 4 years
Plot	Soil treatment applied	Bushels or tons per acre								Value per acre	
	Land Tile-drained										
103	Residues, limestone, phosphorus	26.5	1.0	15.1	1.03	31.2	20.1	13.2	(.35)	$27.03	$42.36
106	Residues, limestone, phosphorus	43.5	1.3	15.6	1.03	33.7	21.6	16.1		33.62	46.77
109	Crop residues	51.3	1.4	11.8	.90	48.5	18.5	4.8	(.15)	33.02	39.74
110	Farm manure	57.0		3.8	.65	39.4	18.1	5.3	.70	27.91	39.80
113	Manure, limestone, phosphorus	57.0		19.8	1.55	39.0	26.6	25.6	2.21	43.11	71.43
116	Manure, limestone, phosphorus	67.5	2.9	17.9	1.23	41.6	26.2	26.3		46.44	72.43
	Land not Tile-drained										
123	Residues, limestone, phosphorus	26.6	.8	13.1	.90	37.9	20.8	11.1	(.39)	$24.68	$44.17
126	Residues, limestone, phosphorus	28.4	1.8	8.4	1.33	25.3	19.5	4.2		25.60	33.64
129	Crop residues	13.1		0.0	.67	17.7	10.3	.7	(.00)	8.61	16.98
130	Farm manure	47.0		1.5[2]	.64	18.7	10.8	.7	.34	21.34	19.88
133	Manure, limestone, phosphorus	59.6	.5	12.0	1.80	30.0	20.2	10.6	1.73	40.56	48.50
136	Manure, limestone, phosphorus	59.1	.8	14.3	1.55	36.9	21.8	18.3		40.86	57.91
	Average of both Tiled and Untiled Land										
	Residues, limestone, phosphorus	31.2	1.2	13.0	1.07	32.0	20.5	11.1	(.37)	$27.73	$41.73
	Crop residues	32.2	.7	5.9	.79	33.1	14.4	2.8	(.08)	20.82	28.36
	Farm manure	52.0	.7	2.7	.65	29.0	14.4	3.0	.52	24.63	29.84
	Manure, limestone, phosphorus	60.8	1.0	16.0	1.53	36.9	23.7	20.2	1.97	42.74	62.57
	Organic manures, limestone, phosphorus	46.0	1.1	14.5	1.30	34.4	22.1	15.7		$35.23	$52.15
	Organic manures	42.1	.7	4.3	.72	31.0	14.4	2.9		22.72	29.10
	Increase due to limestone and phosphorus	3.9	.4	10.2	.58	3.4	7.7	12.8		$12.51	$23.05

[1] Figures in parentheses indicate bushels of seed; the others tons of hay.

[2] Estimated.

TABLE 6.—CROP YIELDS IN SOIL EXPERIMENTS FAIRFIELD FIELD: SERIES 200

Plot	Gray silt loam on tight clay; lower Illinois glaciation Soil treatment applied	Soybeans 1905	Wheat 1906	Clover[1] 1907	Corn 1908	Cowpeas 1909	Wheat 1910	Clover[2] 1911	Corn 1912	Value 1st 4 years	Value 2d 4 years
		Bushels or tons per acre								Value per acre	
	Land Tile-drained										
203	Residues, limestone, phosphorus	3.0	1.3	.47	22.4	3.9	29.41	(.00)	40.7	$14.57	$38.72
206	Residues, limestone, phosphorus	2.4		.52	22.2	3.9	30.0	(.00)	38.1	14.20	38.23
209	Crop residues	3.3	.3	.20	28.5	8.3	20.2	(.00)	22.3	14.69	30.25
210	Farm manure	1.6	1.2	.51	37.9	8.4	20.9	.41[3]	22.3	18.76	33.30
213	Manure, limestone, phosphorus	1.8	2.8	.90	39.0	6.6	38.1	.99	60.6	22.81	60.42
216	Manure, limestone, phosphorus	1.8	2.0	.78	35.3	6.8	36.8		54.5	20.23	57.57
	Land not Tile-drained										
223	Residues, limestone, phosphorus	2.7	2.8	.80	30.9	11.6	31.6	(.00)	29.7	$20.28	$44.11
226	Residues, limestone, phosphorus	2.9	1.2	.76	21.2	4.9	28.6	(.00)	7.4	15.72	27.51
229	Crop residues	2.2		.61	15.6	3.8	7.2	(.00)	1.6	11.32	9.40
230	Farm manure	1.6	1.6	.66	30.3	6.4	16.4	.39[3]	4.0	17.29	21.62
233	Manure, limestone, phosphorus	.8	1.1	.85	38.3	7.7	35.2	.85	22.0	20.07	45.14
236	Manure, limestone, phosphorus	2.9	5.3	1.20	40.4	7.1	36.7		23.8	27.95	46.22
	Average of both Tiled and Untiled Land										
	Residues, limestone, phosphorus	2.8	1.7	.64	24.2	6.1	29.9	(.00)	29.0	$16.19	$37.14
	Crop residues	2.8	.1	.40	22.0	6.0	13.7	(.00)	12.0	13.00	19.83
	Farm manure	1.6	1.4	.59	34.1	7.4	18.7	.40	13.1	18.02	27.46
	Manure, limestone, phosphorus	1.8	2.8	.93	38.2	7.0	36.7	.92	40.2	22.77	52.34
	Organic manures, limestone, phosphorus	2.3	2.2	.79	31.2	6.6	33.3		34.6	$19.48	$44.74
	Organic manures	2.2	.8	.49	28.0	6.7	16.2		12.6	15.51	23.65
	Increase due to limestone and phosphorus	.1	1.4	.30	3.2	–.1	17.1		22.0	$ 3.97	$21.09

[1] Mostly redtop.

[2] Figures in parentheses indicate bushels of seed; the others tons of hay.

[3] Mostly weeds and foul grass.

TABLE 7.—CROP YIELDS IN SOIL EXPERIMENTS, FAIRFIELD FIELD: SERIES 300

Plot	Gray silt loam on tight clay; lower Illinois glaciation	Clover 1906	Corn 1907	Cow-peas 1908	Oats 1909	Clover[1] 1910	Corn 1911	Soybean hay 1912	Wheat 1913	Value 1st 4 years	Value 2d 4 years
	Soil treatment applied	Bushels or tons per acre								Value per acre	
	Land Tile-drained										
303	Residues, limestone, phosphorus	.09	40.8	5.7	37.5	(1.45)	34.3	1.58	14.3	$31.77	$40.19
306	Residues, limestone, phosphorus	.15	37.2	9.6	34.2		34.9	1.80	14.3	33.78	41.72
309	Crop residues	.10	32.1	4.7	25.8	(.00)	25.9	.53	.6	24.27	12.67
310	Farm manure	.25	35.3	5.4	30.8	.76[2]	30.5	1.29	3.1	28.49	25.15
313	Manure, limestone, phosphorus	.40	50.5	10.3	30.2	3.94	39.8	1.66	19.8	39.44	61.39
316	Manure, limestone, phosphorus	.48	48.5	12.7	44.4		36.6	2.68	25.7	45.88	70.52
	Land not Tile-drained										
323	Residues, limestone, phosphorus	.49	39.0	8.4	33.6	(1.95)	34.0	1.87	14.0	$35.07	$44.62
326	Residues, limestone, phosphorus	.51	51.8	9.5	37.8		39.2	1.56	17.0	42.03	46.68
329	Crop residues	.20	34.2	5.3	29.9	(.00)	24.2	.97	2.2	27.44	15.83
330	Farm manure	.39	42.1	7.4	34.2	1.06[2]	31.8	.99	3.2	34.74	25.67
333	Manure, limestone, phosphorus	.40	52.7	9.0	32.5	3.71	34.0	2.15	15.0	39.59	57.56
336	Manure, limestone, phosphorus	.56	52.0	9.7	47.5		28.8	2.04	16.6	45.51	56.20
	Average of both Tiled and Untiled Land										
	Residues, limestone, phosphorus	.31	42.2	8.3	35.8	(1.70)	35.6	1.70	14.9	$35.66	$43.31
	Crop residues	.15	33.1	5.0	27.9	(.00)	25.0	.75	1.4	25.86	14.25
	Farm manure	.32	38.7	6.4	32.5	.92	31.0	1.14	3.1	31.62	25.41
	Manure, limestone, phosphorus	.46	50.9	10.4	38.7	3.82	34.8	2.13	19.3	42.61	61.42
	Organic manures, limestone, phosphorus	.38	46.6	9.3	37.2		35.2	1.92	17.1	$39.13	$52.36
	Organic manures	.23	35.9	5.7	30.2		28.0	.94	2.2	28.74	19.83
	Increase due to limestone and phosphorus	.15	10.7	3.6	7.0		7.2	.98	14.9	$10.39	$32.53

[1] Figures in parentheses indicate bushels of seed; the others tons of hay.

[2] Mostly weeds and foul grass.

TABLE 8.—CROP YIELDS IN SOIL EXPERIMENTS, FAIRFIELD FIELD: SERIES 400

Plot	Gray silt loam on tight clay; lower Illinois glaciation Soil treatment applied	Corn 1906	Cow-peas 1907	Wheat 1908	Cow-peas 1909	Corn 1910	Soy-beans 1911	Wheat 1912	Soy-beans 1913	Value 1st 4 years	Value 2d 4 years
		Bushels per acre								Value per acre	
	Land Tile-drained										
403	Residues, limestone, phosphorus	34.8	3.5	16.0	5.0	55.1	10.6	12.5	9.9	$31.88	$48.53
406	Residues, limestone, phosphorus	38.2	3.1	14.0	7.2	60.9	12.4	13.2	10.5	33.47	53.45
409	Crop residues	32.6	3.2	5.3	7.2	44.4	11.5	1.7	9.9	25.52	38.13
410	Farm manure	41.0	3.4	10.6	6.9	43.8	10.2	2.1	9.3	32.07	36.30
413	Manure, limestone, phosphorus	50.8	8.2	21.8	6.7	66.9	14.7	13.3	12.2	47.94	59.62
416	Manure, limestone, phosphorus	49.2	7.7	21.3	6.5	64.9	15.2	13.1	11.7	46.33	58.79
	Land not Tile-drained										
423	Residues, limestone, phosphorus	47.2	8.0	14.9	5.8	60.9	11.7	14.0	13.4	$40.75	$56.21
426	Residues, limestone, phosphorus	38.6	2.4	10.0	4.8	57.7	13.4	9.3	11.0	27.71	51.10
429	Crop residues	33.0	1.8	2.8	6.5	37.6	9.1	1.0	7.5	21.81	30.46
430	Farm manure	40.3	2.2	1.4	5.4	47.5	8.8	1.1	8.2	22.68	34.40
433	Manure, limestone, phosphorus	48.8	6.6	15.1	4.7	63.6	10.6	13.6	11.4	38.95	53.78
436	Manure, limestone, phosphorus	53.0	4.3	16.3	6.0	65.1	15.5	10.4	12.1	40.26	57.67
	Average of both Tiled and Untiled Land										
	Residues, limestone, phosphorus	39.7	4.2	13.7	5.7	58.7	12.0	12.2	11.2	$33.45	$52.32
	Crop residues	32.8	2.5	4.0	6.9	41.0	10.3	1.3	8.7	23.67	34.29
	Farm manure	40.7	2.8	6.0	6.1	45.7	9.5	1.6	8.8	27.37	35.35
	Manure, limestone, phosphorus	50.4	6.7	18.6	6.0	65.1	14.0	12.6	11.9	43.37	57.47
	Organic manures, limestone, phosphorus	45.0	5.4	16.1	5.9	61.9	13.0	12.4	11.6	$38.41	$54.90
	Organic manures	36.8	2.7	5.0	6.5	43.3	9.9	1.4	8.8	25.52	34.82
	Increase due to limestone and phosphorus	8.2	2.7	11.1	-.6	18.6	3.1	11.0	2.8	$12.89	$20.08

As a general average of both systems of farming on both the tiled and the untiled land, on all series, the increases produced by limestone and phosphorus during the first rotation were valued at $9.94[1] an acre, or about the cost of these materials delivered at most railroad stations in southern Illinois. The values of the increases in the second rotation averaged $24.19, or nearly two and one-half times the cost of the second application of both limestone and phosphate. These increases should be still further augmented in the third rotation because of the larger amount of organic manures to be returned to the better yielding land and because of the continued positive enrichment of the soil in phosphorus and limestone.

During the first four years, the limestone and phosphate, costing $10, produced a gain valued at $7.42 when applied without organic matter, and a gain of $12.46 when applied with farm manure; and during the second four years the increases due to $10 worth of limestone and phosphate were valued at $19.44 when applied with crop residues and $28.93 when applied with farm manure. By referring to the Appendix (page 57), it will be seen that on the Fairfield field potassium salts have produced almost no effect when used in connection with farm manure; whereas the largest effect thus far secured from limestone and phosphate has been obtained where these materials are applied with farm manure. It will be noted, however, that their effect was greater with crop residues during the second rotation than with farm manure during the first. Since the use of crop residues in these experiments was not begun until four years after the first application of manure, no conclusion is justified as to whether the residue system or the manure system will ultimately prove best for this soil. The important thing is that the soil can be profitably enriched by either. A cross comparison of the average crop values of the four series of plots shows the value of four crops as $25.41 with the use of farm manure and $24.18 with the use of crop residues, and perhaps this is reasonably trustworthy. Where limestone and

TABLE 9.—CROP VALUES PER ACRE, FAIRFIELD EXPERIMENT FIELD

First Rotation: Average of Four Series				
Soil treatment	None	Farm manure	Limestone Phosphate	Farm manure Limestone Phosphate
Value of four crops	$20.84	$25.41	$28.26	$37.87
Second Rotation: Average of Four Series				
Soil treatment	Crop residues	Farm manure	Crop residues Limestone Phosphate	Farm manure Limestone Phosphate
Value of four crops	$24.18	$29.51	$43.62	$58.45

[1]Attention is here called to the fact reported in the Appendix (page 57) that at Fairfield where potassium salts are applied to one half of the land under experiment they produce practically no effect on the manured land, while the effect is very appreciable on the unmanured land. Altho the potassium salts are applied to one half of the check plots the same as to one half of the land receiving limestone and phosphorus, so that the $9.94 is the actual increase produced by the limestone and phosphorus above the return from the land otherwise treated the same, nevertheless there is a possibility that on part of the land represented in this result the effect of the potassium salts was different where used with limestone and phosphorus than where used alone. No potassium salts had been applied to the land where the accompanying photographs were taken.

phosphate are also used, the corresponding values are $37.87 with manure and $43.62 with residues, but this is not a fair comparison because the last value ($43.62) was secured where two applications of limestone and phosphate had been made (see Table 9).

In Table 9 are summarized concisely the results of the eight years' work. When considered in relation to the possible profitable improvement of the most extensive soil type in Bond county, the importance of these figures can scarcely be estimated. It should be remembered, too, that this soil is also the most common type in about twenty counties in southern Illinois.

Here we have untreated, well-rotated land producing $20.84 per acre in four years; while $58.45 is the value at the same prices for the same four crops on land receiving three natural fertilizers—farm manure, ground limestone, and fine-ground raw rock phosphate. If it costs $5 an acre a year to farm the un-

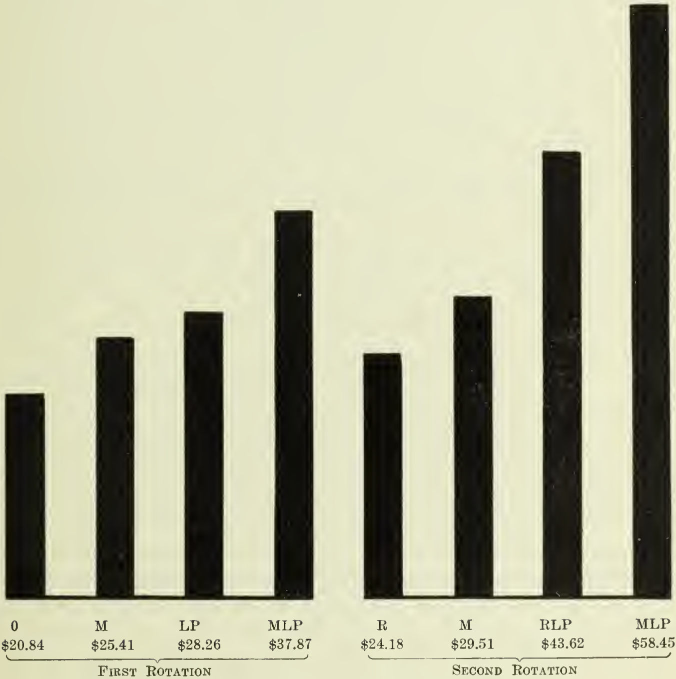


PLATE 5.—CROP VALUES FOR FOUR YEARS FAIRFIELD EXPERIMENT FIELD

(L=lime or limestone; R=residues; P=phosphorus; K=potassium, or kalium; N=nitrogen; M=manure)

treated land, only 21 cents remains to pay the taxes, with nothing for interest; moreover, the practice of leaving land untreated means a gradual soil depletion, which leads only to future poverty and ruin. If the land would sell at $50 an acre and if money is worth 5 percent, then there is essentially an annual expense of $2.50 an acre for which there is no return; but if $2.50 per acre per annum is invested in limestone and phosphate in a rational system of farming, it pays back an average of 100 percent during the first rotation, and of 194 to 289 percent during the second rotation; and this is in addition to the returns from the crop residues and farm manure. Moreover, this is a system of positive soil enrichment which leads to the protection of property and to prosperity.

The crop residues include the corn stalks, straw from wheat or oats and from soybeans or cowpeas, cover crops, and all clover except the seed. In the live-stock system as many tons of fresh manure are applied to the land as the average number of tons of air-dry produce taken off in crops during the previous rotation—an amount easily produced by using the crops for feed and bedding.

The prices used in all these computations are 35 cents a bushel for corn, 30 cents for oats, 70 cents for wheat, $1 for soybeans and cowpeas, $6 for clover seed, and $6 a ton for hay. These prices are stated conservatively in order to avoid any possible exaggeration. If higher prices were used, the computed returns from the land and treatment would of course be increased accordingly. In some localities the expense of hauling will be greater than in others; but it is believed that the prices used provide ample margin for average conditions. The data are reported in detail so that any one can make other computations if desired.

Results from some other field experiments are recorded in connection with the description of individual soil types.

THE SUBSURFACE AND SUBSOIL

In Tables 10 and 11 are recorded the amounts of plant food in the subsurface and the subsoil of Bond county. It should be remembered that these supplies are of little value unless the top soil is kept rich. Probably the most important information contained in these tables is that the common soils of the county are much more strongly acid in the subsurface and the subsoil than in the surface. This emphasizes the importance of having plenty of limestone in the surface to neutralize the acid moisture which rises from the lower strata by capillary action during periods of partial drouth, which are critical periods in the life of such plants as clover. Thus, while the deep brown silt loam bottomland and the black silt loam on clay of the prairie are practically neutral, the vast areas of the common soils of the county are greatly in need of limestone; and, as already explained, the extensive upland soils are markedly in need of phosphorus and nitrogen.

TABLE 10.—FERTILITY IN THE SOILS OF BOND COUNTY

Average pounds per acre in 4 million pounds of subsurface soil (about 6⅔ to 20 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity present
	Upland Prairie Soils								
330	Gray silt loam on tight clay	26 100	2 990	1 530	57 540	10 970	9 500		3 070
328	Brown-gray silt loam on tight clay	26 460	2 700	1 740	63 820	10 160	10 400		300
329	Drab silt loam	43 400	4 160	2 040	61 560	12 120	15 800		280
331	Deep gray silt loam	27 720	3 200	1 080	53 800	7 800	9 600		5 600
325.1	Black silt loam on clay	91 680	7 320	1 880	63 120	20 600	31 160		40
	Upland Timber Soils								
334	Yellow-gray silt loam	21 240	2 600	1 340	75 500	14 620	8 520		5 200
335	Yellow silt loam	16 980	2 120	1 270	73 820	15 400	8 570		4 080
332	Light gray silt loam on tight clay	11 560	1 400	1 260	60 160	14 260	7 320		10 020
332.1	White silt loam on tight clay	7 960	1 000	1 480	61 400	11 560	10 080		960
	Ridge Soils								
235	Yellow silt loam	15 520	2 080	1 000	82 400	12 960	13 840		80
233	Grey-red silt loam on tight clay	44 960	4 800	1 440	54 000	24 240	12 760		5 880
245	Yellow fine sandy silt loam	18 520	2 340	1 620	79 900	18 280	11 100		320
	Bottom-Land Soils								
1331	Deep gray silt loam	23 480	2 720	2 200	74 000	16 080	10 280		4 320
1326	Deep brown silt loam	30 200	2 880	1 800	69 040	14 120	14 600		160

TABLE 11.—FERTILITY IN THE SOILS OF BOND COUNTY

Average pounds per acre in 6 million pounds of subsoil (about 20 to 40 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity present
	Upland Prairie Soils								
330	Gray silt loam on tight clay	27 900	3 340	2 850	88 940	36 180	21 210		2 050
328	Brown-gray silt loam on tight clay	19 650	2 760	2 520	97 290	35 730	31 830		often
329	Drab silt loam	36 060	3 720	3 180	89 580	27 300	22 860		540
331	Deep gray silt loam	37 920	3 720	2 280	79 560	31 620	15 600		18 300
325.1	Black silt loam on clay	34 920	3 060	2 760	94 260	37 620	39 840		120
	Upland Timber Soils								
334	Yellow-gray silt loam	16 260	2 190	2 580	118 140	31 470	18 030		12 540
335	Yellow silt loam	12 790	2 170	2 090	105 290	32 240	12 910		15 070
332	Light gray silt loam on tight clay	15 840	2 070	2 670	96 480	30 090	11 460		21 720
332.1	White silt loam on tight clay	10 560	1 860	2 820	96 540	38 700	18 000		25 380
	Ridge Soils								
235	Yellow silt loam	14 220	2 280	2 520	121 260	35 700	21 060		2 340
233	Grey-red silt loam on tight clay	20 220	2 040	1 980	114 600	48 120	38 040		often
245	Yellow fine sandy silt loam	21 060	2 760	2 960	116 040	37 260	24 780		2 010
	Bottom-Land Soils								
1331	Deep gray silt loam	12 060	2 040	3 060	108 240	26 520	11 880		20 100
1326	Deep brown silt loam	21 540	2 520	2 580	106 140	15 840	19 380		420

INDIVIDUAL SOIL TYPES

(a) UPLAND PRAIRIE SOILS

The upland prairie soils of Bond county occupy 190 square miles, or 51 percent of the entire area of the county. Because of their larger content of organic matter, they are usually darker in color than the upland timber soils of similar topography.

The accumulation of organic matter in the prairie soils is due to the growth of prairie grasses that once covered them, and whose network of roots has been protected from complete decay by imperfect aeration resulting from the covering of fine soil material and the moisture it contains. The tops of these prairie grasses contributed little organic matter, as they were usually burned by prairie fires or soon became almost completely decayed from exposure to the air. Because of its great age and the loss of mineral plant food by leaching, the most common prairie soil of the lower Illinois glaciation has finally become incapable of supporting such a rank vegetation as the more recently formed and more fertile prairies of the corn belt in central and northern Illinois. Consequently, the southern Illinois prairies are not so rich in organic matter and nitrogen as the corresponding corn-belt soils; indeed, they differ but little from the best timber soil.

Gray Silt Loam on Tight Clay (330)

Gray silt loam on tight clay is the predominating soil type in the lower Illinois glaciation. It covers 121.49 square miles (77,754 acres), or 32.66 percent of the area of the county. In topography it is nearly level or gently undulating, tho somewhat rolling in places.

The type varies primarily in: (1) the organic-matter content; (2) the topography and consequent surface drainage; and (3) the thickness, depth, and density of the tight clay layer underlying it. Where adjoining the somewhat rolling areas of this or other types, or in the vicinity of ridges, this type has received some wash, which has buried the tight clay layer to such a depth that it is less objectionable, and in such places the soil is better than the average soil of this type. On the other hand, where erosion has been somewhat active, the tight layer is near the surface, making a very unproductive soil.

This type contains many small areas known as "scalds" or "scald spots," readily recognized in the plowed field by their light color. On these spots the ordinary surface soil, and in many cases the subsurface soil, is partly or entirely absent, leaving the subsoil on or very near the surface. Ordinarily these spots constitute only a few square rods; occasionally, tho very rarely, one is found covering an acre or more. These "scalds" are very irregular in their occurrence, some fields being almost free from them while others contain many. Bracted plantain (*Plantago aristata*) of stunted growth is a common plant on these "scalds."

The surface stratum, 0 to 6⅔ inches, is a friable silt loam, varying in color from a light to a dark gray and containing sufficient clay to make it slightly plastic when wet. A few small gravels of quartz and concretions of hydrated iron oxid are sometimes found in it. The organic-matter content varies from 1.9 to 2.6 percent; in other words, from 19 to 26 tons per acre, or an average of 22 tons. The surface soil is fairly pervious to water, but the low organic-matter

content, and the consequent lack of granulation, renders it in poor tilth, causing it to "run together" readily with heavy rains or with freezing and thawing when very wet. The chief variation in the surface stratum is due to the variation in the organic-matter content. Analysis shows from 10 to 13 percent of the various grades of sand and from 70 to 80 percent of silt.

The subsurface stratum varies greatly in thickness. In many of the "scalds" it is entirely absent, while in other places the depth to the subsoil is two feet or more. The average thickness is about 13 inches. It contains 1.1 percent of organic matter, and consists of a silt loam varying in color from gray to almost white. The upper part of the stratum is sometimes about the same color as the surface soil, but ordinarily the plow-line marks the beginning of a much lighter colored soil, which becomes still lighter with depth and passes into a distinct light gray layer deficient in organic matter, close-grained, very compact when dry, and very slowly pervious to water. When saturated, it is soft, and posts may be driven thru it readily. A few small quartz gravels and some concretions of hydrated iron oxid are sometimes present.

The natural subsoil lies at an average depth of about 20 inches from the surface, but the distance varies from only a few inches on the "scalds" to two feet or more on the best phase of the type. It is usually made up of two distinct layers. The upper layer, extending from the subsurface to an average depth of 30 to 36 inches, consists of tight clay, sometimes erroneously called "hard-pan," while the lower subsoil is friable, porous, and silty. The tight clay stratum varies from 4 to 12 inches in thickness and is usually a close, silty clay, reddish or yellowish in color, very sticky and gummy when wet, and very hard when dry. Water percolates thru it very slowly.

Because of the level topography and the tight clay subsoil, the drainage of this type is, as a rule, rather poor. It is still a question whether the type can be tile-drained profitably; experiments are now in progress with the view of answering this question.

The soil is strongly acid and low in nitrogen content. It is in poor physical condition; it "runs together" badly during rains, is too compact for good aeration, and is very unfavorable for moisture movement. Therefore in the management of this type the chief essentials are the application of limestone and the increase of organic-matter content by every practical means.

Limestone is needed, not only to correct soil acidity, but to supply calcium as plant food as well. It also increases granulation, or flocculation, and thus improves the tilth. About two tons per acre of ground limestone should be applied every four or five years, and the initial application may well be from four to six tons.

In order to increase the organic-matter content, all forms of vegetation, such as weeds, manure, straw, corn stalks, etc., should be plowed under and no part of them burned. Legume crops, such as cowpeas, soybeans, and red, alsike, or sweet clover, should be grown and turned back into the soil, or fed and the manure returned. Probably no crop will prove better adapted to adding organic matter and nitrogen to the soil than the common sweet clover (*Melilotus alba*), a deep-rooting plant which will also help to loosen the tight subsoil and make it more pervious. In order to grow this clover, the soil must be sweetened with ground limestone and well inoculated with nitrogen-fixing bacteria.

This type is also markedly deficient in phosphorus, especially for the growing of such crops as wheat and clover; hence in permanent systems of improvement a liberal use of phosphorus is essential. This is applied most economically in the form of fine-ground natural rock phosphate, which should be plowed under in intimate contact with farm manure, clover, or cowpeas. If one-half ton per acre is applied every four or five years, the phosphorus content of the soil will be maintained or slowly increased, but an application of one or two tons at one time gives still better results. With the increase in organic matter, the phosphorus content of the plowed soil should be raised finally to at least 2,000 pounds per acre, which will require altogether about five tons of rock phosphate.

This system of permanent soil improvement can be hastened, and sometimes with profit during the early years, by applying about 600 pounds of kainit per acre to be plowed under with the initial application of rock phosphate. The action of kainit is explained in the Appendix (see page 57). If used at all it should be with the understanding that it serves in part, at least, as a soil stimulant; and that when plenty of decaying organic matter is provided, the use of kainit may not be profitable. The benefit derived from ground limestone, where a heavy application is made, seems to include some of the effect of soluble salts and to make the use of kainit less important.

For results of field experiments on this soil type, see Tables 3 to 9.

Brown-Gray Silt Loam on Tight Clay (328)

Brown-gray silt loam on tight clay covers 61.49 square miles (39,354 acres), or 16.54 percent of the entire county. The principal area is located between the east and the west branches of Shoal creek. Other large areas are found near Smithboro and east of Stubblefield. With few exceptions the topography is flat or only slightly undulating.

This type contains many "scalds" where the subsoil comes to the surface or injuriously near it, usually less than ten inches. These "scalds" are very irregular in their occurrence, some fields being devoid of them, while others contain many. They are indicated by their lighter color, distinctly seen when the ground is plowed.

The surface soil, 0 to 6⅔ inches, is a dark gray to a brown mealy silt loam, varying in color with its gradation toward other types. It contains about 2.4 percent of organic matter, or 24 tons per acre. The amount varies from 2.1 to 3 percent, or from 21 to 30 tons per acre. The mineral part of the soil is composed of 80 to 85 percent of the different grades of silt with 10 to 12 percent of sand, and some clay. Coarse silt seems to be the most abundant constituent. The soil is porous, friable, and easy to work.

The subsurface stratum varies greatly in thickness and color. Its average thickness is from 10 to 12 inches, altho it is entirely absent in some places, such as "scalds," and 18 inches thick in others. It consists chiefly of a grayish brown silt loam, the color becoming lighter with depth. Usually there is a distinct gray or grayish brown layer from 2 to 10 inches thick just above the subsoil. Where the type grades into gray silt loam on tight clay (330), this gray layer in some places becomes quite well developed. On the other hand, where the type grades toward brown silt loam this layer becomes quite indistinct.

The subsoil is found at variable depths, from only a very few inches from the surface on the "scalds" to 20 inches or more on the better phases. It consists of two distinct layers. The upper stratum, from 5 to 16 inches thick, is a plastic, gummy, yellow, drab or dark olive-colored clay, very tight and nearly impervious to water. Below it is a clayey silt, friable and pervious, of a yellow color, or yellow with drab mottlings.

The upper layer of the subsoil is too nearly impervious to allow good drainage, so that special surface drainage in the form of dead furrows must be provided. Probably the lower, flatter land of this type should be tile-drained, the lines of tile being placed not over five rods apart. This opinion is based merely upon observation and reported experience, as no definite experiments in tile drainage have been conducted on this type.

In the improvement of this type practically the same methods should be employed as for the gray silt loam on tight clay (330). All crop residues and legume crops not fed on the farm should be turned back into the soil in order to provide nitrogen, liberate mineral plant food, and aid in the physical improvement of the soil. Deep-rooting crops should be grown in order to loosen up the subsoil and provide more rapid percolation of water and air.

This type contains no limestone, and is usually somewhat acid. However, it is not so sour as the gray silt loam on tight clay, and this fact, together with the higher content of calcium and organic matter and some ability to grow clover in favorable seasons, has made it a more productive soil, generally, than the gray prairie. It has been much used for wheat, and possibly because of the many crops removed, this type in Bond county is, as an average, more deficient in phosphorus than the more extensive gray silt loam on tight clay. Where it has long been cropped it is also very poor in active organic matter, so that nitrogen is one of the important factors which now limit the yield of grain crops.

In Table 12 are given the data secured from twelve years' field investigations on brown-gray silt loam on tight clay, on the soil experiment field near Mascoutah, St. Clair county, which almost corners Bond county on the southwest. These data are from a part of the Mascoutah field where commercial nitrogen, phosphorus, and potassium have all been used in readily available form in order to secure information as quickly as possible. The regular applications per acre have been 100 pounds of nitrogen in 700 pounds of dried blood every year, and 800 pounds of steamed bone meal and 400 of potassium sulfate every four years, corresponding to 25 pounds of phosphorus and 42 of potassium for each year of the rotation.

At the time these experiments were begun the claim was commonly made, especially by lime manufacturers, that small amounts of slaked lime should be applied frequently to soils. (The product was sold under the name of "hydrated" lime at \$6 to \$10 per ton.) On the Mascoutah field this material was tried, 400 pounds per acre in 1902 and 700 pounds in 1903. No further applications were made until 1909, when the use of ground limestone was begun. At that time 1½ tons per acre was applied, and four years later 2 tons per acre was applied. The first distinct indication of benefit from lime alone appeared in 1913.

Nitrogen is clearly the element of greatest benefit on the Mascoutah field, as shown by the fact that the dried blood has increased the crop values, in twelve

years, from $91.05 to $135.50, a gain of $44.45. In comparison, phosphorus has produced an increase valued at $16.60, and potassium an increase valued at only $10.63, when used singly. All other results harmonize well with these values, except those from Plot 507, which indicate a very marked influence from potassium. In fact, the crop values from this plot, which has received lime, nitrogen, and potassium, are $15.17 higher than those from Plot 509, which has received lime, nitrogen, phosphorus, and potassium. However, nearly $13 of this

TABLE 12.—CROP YIELDS IN SOIL EXPERIMENTS, MASCOUTAH FIELD

Brown-gray silt loam on tight clay; middle Illinois glaciation		Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912[1]	Wheat 1913
Plot	Soil treatment applied	Bushels per acre											
501	None	32 5	43.4	17.5	9.1	31.7	29.1	8.8	20.7	8.8	11.6		9.8
502	Lime	32.0	38.9	22.5	7.8	30.8	31.9	6.6	17.5	8.8	11.2		15.5
503	Lime, nitro	24.2	47.1	40.0	16.7	53.1	45.8	12.2	20.8	12.4	19.8		32.5
504	Lime, phos	34.4	39.3	68.7	15.0	21.6	24.8	9.1	20.2	6.8	14.6		14.5
505	Lime, potas	37.5	47.8	25.6	15.7	22.3	32.5	10.6	18.0	10.4	17.0		12.3
506	Lime, nitro., phos.	46.1	69.9	44.1	25.3	56.7	58.8	28.8	32.7	32.4	39.2		33.5
507	Lime, nitro., potas.	59.6	77.4	43.1	30.2	59.6	70.0	37.2	30.7	32.0	48.8		27.0
508	Lime, phos., potas.	53.9	49.0	33.1	20.0	19.6	38.1	12.2	22.3	15.2	19.6		18.8
509	Lime, nitro., phos., potas	47.8	70.5	37.8	28.3	49.6	70.0	30.3	33.7	34.4	37.4		28.3
510	Nitro., phos., potas.	47.7	52.6	35.9	26.3	42.9	65.3	32.2	33.7	34.8	28.6		30.5
Average Increase: Bushels per Acre													
For nitrogen		–7.8	8.2	17.5	8.9	22.3	13.9	5.6	3.3	3.6	8.6		17.0
For phosphorus		2.4	.4	46.2	7.2	–9.2	–7.1	2.5	2.7	–2.0	3.4		–1.0
For potassium		5.5	8.9	3.1	7.9	–8.5	.6	4.0	.5	1.6	5.8		–3.2
For nitro., phos. over phos		11.7	30.6	–24.6	10.3	35.1	34.0	19.7	12.5	25.6	24.6		19.0
For phos., nitro. over nitro		21.9	22.8	4.1	8.6	3.6	13.0	16.6	11.9	20.0	19.4		1.0
For potas., nitro., phos. over nitro., phos.		1.7	.6	–6.3	3.0	–7.1	11.2	1.5	1.0	2.0	–1.8		–5.2

Value of Crops per Acre in Twelve Years

Plot	Soil treatment applied	Total value of twelve crops	Value of increase
501	None	$ 90.60	
502	Lime	91.05	$ .45
503	Lime, nitrogen	135.50	44.90
504	Lime, phosphorus	107.65	17.05
505	Lime, potassium	101.68	11.08
506	Lime, nitrogen, phosphorus	192.01	101.41
507	Lime, nitrogen, potassium	207.21	116.61
508	Lime, phosphorus, potassium	124.75	34.15
509	Lime, nitrogen, phosphorus, potassium	192.04	101.44
510	Nitrogen, phosphorus, potassium	178.95	88.35

Value of Increase per Acre in Twelve Years		Cost of increase
For nitrogen	$44.45	$180.00
For phosphorus	16.60	30.00
For *nitrogen* and phosphorus over phosphorus	84.36	180.00
For *phosphorus* and nitrogen over nitrogen	56.51	30.00
For *potassium,* nitrogen, and phosphorus over nitrogen and phosphorus	.03	30.00

[1] The oat crop failed in 1912.

difference is found in the first five crops, which suggests the possible influence of some unknown factor in Plot 507, such as the presence of an old stack bottom. But even if this abnormal effect during those years is disregarded, the data still show a slightly greater benefit from nitrogen and potassium (507) than from nitrogen and phosphorus (506), altho in 1913 a marked superiority of phosphorus appears in this comparison.

Here again on this highest yielding plot (507) we meet what seems to be the stimulating influence of the soluble potassium salt. If, however, the treatment used on this plot were practiced, it would lead ultimately only to failure and land ruin, for it makes no provision for the restoration or the maintenance of phosphorus, which is unquestionably the most deficient of the five most important elements of plant food. The only guide toward a safe practice for permanent systems of improvement is the chemical composition of the soil.

In the lower part of Table 12 is shown the influence of each element in a rational order of application. From the composition of the soil it is clear that both nitrogen and phosphorus must be supplied for permanent systems of farming, altho there may be some question as to which of these two is most needed, because of imperfect knowledge of the condition of the organic matter and of the rate of decomposition under unknown future weather conditions. It must be plain, however, that if potassium is to be used for its own sake, it should pay a profit when applied in addition to both nitrogen and phosphorus.

In considering these three elements, nitrogen, phosphorus, and potassium, we find that, starting with $91.05 (the value of the crops for twelve years when lime alone was used), the increases per acre in crop values have been as follows:

For nitrogen over lime	$ 44.45
For phosphorus as a further addition	56.51
For potassium as a final addition	.03
For total increase	$100.99

This demonstration of more than doubling crop values is highly important, for it shows the possibilities of soil treatment; but of still more importance is the development of methods of producing the same results with profit to the producer. Applied nitrogen has produced exceedingly marked gains, but never enough to pay its cost in commercial form; and while phosphorus has paid nearly 200 percent on the investment in steamed bone meal when used in addition to nitrogen, the profit is more than offset by the nitrogen deficit.

On another part of the Mascoutah field, investigations are in progress where nitrogen is secured by the slower but less expensive practice of growing legumes in the crop rotation and returning to the soil the crop residues or farm manure. In Table 13 are shown for direct comparison the results secured where commercial nitrogen is used and those where these rational means of securing nitrogen are employed, both on lime-phosphorus plots and on plots where lime, phosphorus, and potassium are applied. The records are taken from the legume rotation of the same crops as were grown in identical years in the experiments reported in Table 12. It will be seen that the rotations differ only by the substitution of a legume crop for one corn crop. The final averages, including duplicate experiments (except for the potassium), may be considered trustworthy, within

rather narrow limits. The data of the first four years are averaged separately because during those years the residue and manure systems were not well under way.

TABLE 13.—CROP YIELDS IN SOIL EXPERIMENTS. MASCOUTAH FIELD

Rotation system.......	Corn, corn, oats, and wheat		Corn, oats, wheat, and clover		Corn, oats, wheat, and clover	
Soil treatment.........	Lime Nitro. Phos.	Lime Nitro. Phos. Potas.	Lime Residues Phos.	Lime Residues Phos. Potas.	Lime Manure Phos.	Lime Manure Phos. Potas.
1902 Corn, bu.........	46.1	47.8	39.6	45.3	42.7	47.1
1903 Corn, bu.........	69.9	70.5	50.8	56.8	43.1	58.9
1904 Oats, bu.........	44.1	37.8	36.9	33.4	32.8	39.4
1905 Wheat, bu........	25.3	28.3	25.9	28.2	26.3	31.2
Value of four crops...	$71.54	$72.55	$60.84	$65.49	$58.28	$70.76
1906 Corn, bu.........	56.7	49.6	57.1	57.3	54.1	49.1
1907 Corn, bu.........	58.8	70.0	70.0	84.3	73.0	93.0
1908 Oats, bu.........	28.8	30.3	9.7	11.3	10.6	13.1
1909 Wheat, bu........	32.7	33.7	32.0	32.7	32.7	33.2
1910 Corn, bu.........	32.4	34.4	28.6	36.0	27.2	35.2
1911 Corn, bu.........	39.2	37.4	38.2	29.4	29.6	32.8
1912 Oats, failed.......						
1913 Wheat, bu........	33.5	28.3	33.5	34.7	32.3	30.2
Value of eight crops....	$120.47	$119.48	$116.63	$123.02	$113.05	$121.84
Av. value of eight crops.	$119.97		$119.82		$117.44	

Where commercial nitrogen has been used, the crop values for the last eight years average $119.97, with a total cost for nitrogen of $120.00; but where crop residues have been used as a source of nitrogen, the average crop value is $119.82, or within 15 cents of that produced with commercial nitrogen. Nearly the same results have been secured where the nitrogen is supplied in farm manure in quantities easily produced from the crops grown on the land.

These data show that altho practically the same aggregate gross values are secured with "home-grown" nitrogen as with the purchased product, the securing of these values requires that the crop of clover seed in the grain system or the clover hay in the live-stock farming shall bring as large a return as the corn crop which it replaces. Even if no value is assigned to the clover crop, the cost of the nitrogen secured by these rational methods is only about one-fourth its cost in commercial form.

Drab Silt Loam (329)

Some of the low and more poorly surface-drained areas of the prairie land have received deposits of finer material washed in from the slightly higher surrounding land, and in these places a greater amount of organic matter has accumulated, more particularly in the surface and the subsurface strata, owing to the more luxuriant growth of vegetation and the better conditions for preventing complete decay. This finer material and the greater accumulation of organic matter have given rise to a type of soil, the drab silt loam (329), which is darker in color, better in texture, and somewhat more productive than the surrounding gray silt loam on tight clay (330), the ordinary prairie land of this glaciation. Drab silt loam in Bond county covers an area of 2.46 square miles (1,574 acres), or .66 percent of the county.

The surface soil, 0 to 6⅔ inches, is a drab to a dark gray. Altho silts form the chief constituent, this stratum always contains some fine sand and, in the poorly drained areas, enough clay to give it some tenacity. The organic matter averages 3.1 percent, or 31 tons per acre.

The subsurface stratum varies from a brownish gray to a light drab, frequently with blotches of iron oxid. The amount of clay varies considerably, the stratum in some areas being very silty, while in others it has sufficient clay to make it plastic; in either case it is pervious to water.

The subsoil, 20 to 40 inches beneath the surface, is a drab to yellowish gray silt or clayey silt. In many areas the subsoil is quite heavy, yet sufficiently pervious so that tile drains should work well.

This type needs underdrainage to bring it to its best condition of tilth and productiveness. The physical composition, texture, and structure indicate that tile drainage would be of great benefit, but actual field experiments are necessary to determine how satisfactorily tile will work.

Besides thoro drainage, one of the most important points in the management of this type is the maintaining or even the increasing of the organic matter in order to provide sufficient nitrogen to meet the needs of large crops of corn and other non-legumes to be grown in the crop rotation. This can best be done by practicing a rotation of crops in which a legume is used as often as practical and by turning back into the soil all crop residues. If these crops are fed on the farm, the manure should be put back with as little waste as possible. This type in Bond county is very deficient in phosphorus and contains no limestone, altho it is not markedly acid; hence both phosphate and limestone should be used.

Deep Gray Silt Loam (331)

Deep gray silt loam occupies low areas in the southeastern part of Bond county where silt has been carried in from the higher lands to such a depth that all evidence of a clay subsoil has been buried to a depth of more than 40 inches. It covers 2.19 square miles (1,401 acres), or .59 percent of the county.

The surface soil, 0 to 6⅔ inches, is a gray to dark gray silt loam, changing in shade as it grades into other types. It contains 2.4 percent of organic matter, or 24 tons per acre.

The subsurface is a silt loam, lighter in color than the surface, and containing 1.2 percent of organic matter.

The subsoil is a gray to drab silt, differing from the subsurface in that it contains less organic matter and has layers of clay or clayey silt developed locally.

The low organic-matter content of this type indicates the necessity of maintaining or increasing the supply by every practical means. Owing to the character of the subsoil, crops growing on this type have a decided advantage over those on gray silt loam on tight clay (330), provided the subsoil is thoroly drained. The greater porosity and deeper feeding range are of no avail when water is present in excess.

Among the prairie soils of Bond county, this type is the most acid and the most deficient in calcium and magnesium; it is also very poor in phosphorus. Phosphate should be applied liberally in connection with organic matter; dolomitic limestone (such as can be secured from Grafton and from most

northern Illinois deposits) will probably give even better results than the more common limestone.

Black Silt Loam on Clay (325.1)

Black silt loam on clay represents low prairie land that was originally swampy. In position, this type corresponds to the black clay loam in the middle and upper Illinois and early Wisconsin glaciations. In Bond county it covers 2.48 square miles (1,587 acres), or .67 percent of the county. The areas are widely scattered; one of the largest is found south of Old Ripley and two others of considerable size east of Greenville.

The surface soil, 0 to 6⅔ inches, is a heavy black silt loam varying in some places to a clay loam. It contains 4.9 percent of organic matter, or 49 tons per acre, an amount sufficient to make it quite granular and keep it in good physical condition if properly drained.

The subsurface extends 15 to 18 inches below the surface soil and is a dark clayey silt loam containing about 4 percent of organic matter.

The subsoil consists of a clay, varying in color from dark to light drab.

The presence of clay and organic matter imparts to this type of soil the property of shrinkage to a very marked degree, and in times of drouth large cracks a foot or more in depth are formed, which sever the roots and damage the crop to some extent. Drainage and good cultivation prevent this to a considerable degree. After drainage, rotation of crops and turning under crop residues such as corn stalks, straw, etc., together with good tillage, is all that is necessary to keep the soil in good physical condition.

This black silt loam is by far the richest prairie soil in the county, not only in phosphorus and nitrogen, but also in calcium and magnesium; it is somewhat the richest, too, in potassium. The ratio of nitrogen to carbon is 1 to 12, which indicates that the organic matter is more active as well as more abundant in this type than in the other prairie types in Bond county, in which the ratio is only 1 to 10. (Read "Supply and Liberation of Plant Food" in the Appendix.) A liberal use of phosphorus with clover in rotation is needed for marked improvement in crop yields on such soil.

No field experiments have been conducted on black silt loam on clay, but its composition is practically the same as the most extensive soil type in the corn belt, the common brown silt loam. When well drained and well farmed with a good crop rotation including clover, phosphorus is the single factor which holds the crop yields far below what they would otherwise be. Thus, on the brown silt loam at the Bloomington soil experiment field, the values per acre of eleven crops (1902-1912) on four different plots where no phosphorus was applied were $165.52 (with lime), $173.17 (with lime, crop residues[1]), $169.66 (with lime, potassium), and $170.57 (with lime, residues,[1] potassium); whereas the corresponding values on four other adjoining or intervening plots whose treatment differed only by the addition of phosphorus were $255.44, $251.43, $256.92, and $254.76. Other essentials are so much better provided than phosphorus that the addition of this element paid 300 percent on the investment.

[1]No values are assigned to crop residues plowed under until they reappear in increased yields of subsequent crops.

(b) Upland Timber Soils

The upland timber soils of Bond county aggregate 126 square miles, or more than one-third of the area. They are usually lighter in color than the prairie soils, because of the more nearly complete decay of the residues of timber vegetation. In upland forests these residues consist of fallen leaves, branches, and dead trees, which become almost completely decomposed thru exposure to the oxygen of the air and to fungi. Even the large roots of trees thru exposure at the stump decay rapidly in the surface soil. Occasional forest fires help to complete the destruction. (As already explained, the most common prairie soil of the lower Illinois glaciation, because of its great age and the loss of mineral plant food by leaching, has been reduced in organic-matter content to about the condition of the undulating timber land.)

Yellow-Gray Silt Loam (334)

Yellow-gray silt loam in Bond county covers 48.76 square miles (31,206 acres), or 13.13 percent of the area of the county. It is found along the streams and generally lies between the eroded zone of yellow silt loam (335) and the prairie types. In topography it is usually undulating, but it varies from nearly level to quite rolling. The normal slopes are long and gentle, but in places very short, abrupt slopes of yellow silt loam occur, which are too small in area to be shown separately on the map.

The surface drainage is generally good. Erosion takes place on many slopes where no means are taken to prevent it. While this type was once generally timbered, it is also sometimes found extending into the prairie along natural drainage channels, and as these particular areas represent recent erosion of the prairie, "scalds," or tight-clay outcrops, are often found, the presence of which renders these narrow areas very inferior to the type as a whole, and in some places, almost worthless. These "scald" areas are rarely over two or three acres in extent and more frequently are only a fraction of an acre, often occurring as narrow strips along the streams or draws.

The surface soil, 0 to 6⅔ inches, is a yellow to grayish yellow silt loam. The freshly plowed surface when first dry after a rain takes on a decidedly grayish appearance. The type varies to a lighter color as it grades into light gray silt loam on tight clay (332), to a darker color as it grades into the prairie types (330 and 328), and to a more yellowish color as it approaches the yellow silt loam. It contains some fine sand, and locally, in small areas, quite appreciable amounts, but the principal constituent is silt of various grades. The organic-matter content is 2.28 percent, or about 23 tons per acre. The surface soil is porous and friable but "runs together" badly because of its shortage in organic matter and lime.

The subsurface, like the surface, varies from a gray or yellowish gray to a yellow silt loam sufficiently porous to permit slow percolation; its physical composition is such that capillary movement takes place very readily. In thickness it varies from 6 to about 16 inches.

The subsoil is a yellow or mottled grayish silt or clayey silt, somewhat compact but pervious. The depth to the natural subsoil is quite variable, owing to the amount of erosion that has taken place, but it commonly varies from 10

to 20 inches. In places, both surface and subsurface have been removed, but this is unusual.

The growth of natural vegetation on this type has done very little toward adding organic matter. In fact, it is more likely true that the growth of forest trees has reduced the content of this constituent in the original soil. At any rate, this type is now deficient in organic matter, and one of the most important problems in its management is to increase this constituent. In order to do this, a rotation must be carefully planned, and all crop residues and legume crops, or their equivalents in manure, put back on the land. Deep-rooting crops, such as red, mammoth, or sweet clover, should be grown; but in order to grow these successfully, applications of ground limestone are necessary. If the soil is to be enriched and its productive power increased and maintained in any permanent way, phosphorus must also be applied, altho the application may well be delayed until, thru the use of limestone and the growth of clover, some organic matter can be turned under; or else kainit should be applied with the phosphorus. Very marked improvement can be made with limestone and the organic matter which it helps to produce.

Field experiments on yellow-gray silt loam in the lower Illinois glaciation were begun in 1910 in Saline county near Raleigh, where the people of the community have provided the University with a very suitable tract of this type of soil for a permanent soil experiment field. There, as an average of triplicate tests each year, the yield of corn on untreated land was 25.3 bushels per acre in 1910, 23.6 in 1911, and 22.0 in 1912, while on duplicate plots treated with six tons per acre of ground limestone and the limited amount of organic manures produced upon the land, the corresponding yields were 41.4 bushels in 1910, 41.3 in 1911, and 50.1 in 1912. These results show an average increase of 20.6 bushels, of which only 6.6 bushels are due to organic manures.

As an average of duplicate tests with each crop each year for three years, the ground limestone increased the yields by 14 bushels of corn, 10.55 bushels of oats, .85 ton of hay (clover or cowpea), and 4.45 bushels of wheat. The value of these increases at 35 cents for corn, 30 cents for oats, 70 cents for wheat, and $6 for hay, amounts to $16.28 and corresponds to the value of the increase produced by limestone on one acre during a four-year rotation. Thus the limestone paid about 200 percent interest on the investment, and the application of 6 tons per acre is sufficient for about fifteen years, altho in order to maintain a liberal amount of limestone in the soil it is well to apply about 2 tons per acre every four or five years after making the heavier initial application.

Owing to the low supply of active organic matter in the soil at Raleigh, phosphorus produced no benefit, as an average, during the first two years; but with the turning under of the crop residues and farm manure in proportion to the crops produced, the effect of phosphorus is seen to some extent in the crops of 1912 and 1913. The fourth series of plots will receive its first farm manure for the 1914 crops, so that trustworthy data as to the benefits of organic matter, or of phosphorus combined with organic matter, will not be secured before the second rotation period.

Where kainit has been used at the rate of 200 pounds for each year, applied in connection with phosphate and in addition to the 6 tons of limestone, the average increase for the kainit during the first three years has been $2.90, or only about half its cost.

Yellow Silt Loam (335)

Yellow silt loam in Bond county includes the broken, very rolling, and hilly land along the streams and sometimes on the steep slopes of ridges. It is best to keep much of it forested, tho when properly treated it makes good pasture land. It is so steeply sloping that little of it should ever be cultivated. When it is cultivated, the utmost care should be taken to prevent washing, which is the most serious danger to this type of soil. Already many fields have been ruined by gullying. This type of soil covers an area of 60.09 square miles (38,458 acres), or 16.15 percent of the county.

The surface soil is a friable yellow silt loam varying somewhat with topography. The less broken areas are a grayish yellow, while the steep slopes are reddish yellow, or brownish yellow where a little more organic matter remains. As a rule, the soil contains enough fine sand to give it a fairly good texture, but it is very deficient in organic matter, having only 2 percent, or 20 tons per acre. This condition contributes toward its excessive washing. "Clay points," or places where the top soil has been removed by washing, are quite common, and they are very unproductive.

The subsurface varies in thickness; where little or no washing has taken place it is from 6 to 14 inches thick. It consists usually of a friable, slightly loamy, yellow silt, mottled with gray or with reddish blotches of iron oxid.

The subsoil is usually a somewhat friable and quite pervious, yellow, clayey silt. Where much washing has occurred, the glacial drift frequently forms the subsoil.

Of most importance in the management of this type is the prevention of much loss by washing. Erosion occurs as sheet-washing and gullying. Ordinarily sheet-washing is not thought of as doing very much damage, but it is really the most injurious form of erosion. Gullying results in the absolute ruin of small areas, but sheet-washing reduces the productive capacity of large areas to such an extent that it prevents not only profitable cropping but even the growing of crops large enough to pay for their raising. Every means should be taken to prevent this loss.

The steep, gullied slopes probably never can be reclaimed with profit for cropping purposes at the present average prices for labor and farm produce. The forests that originally covered these lands should never have been entirely removed. The only thing that made these lands valuable in the first place was the forests, and to make them of any future value they should be reforested. This has been done in a few cases and has met with excellent success. The accompanying illustrations show such results. The black locust can be used most successfully for this purpose, as it is largely independent of the supply of nitrogenous organic matter in the soil, altho it is subject, of course, to insect injury which is sometimes fatal. Where not in forest, the steep land should be kept in pasture as much as possible; if cropped, it should be for only one or two years

PLATE 6.—YOUNG GROVE OF BLACK LOCUST TREES ON ROLLING HILL LAND IN JOHNSON COUNTY, ILLINOIS (GROWN BY J. C. B. HEATON)

at a time and then the land should be reseeded for pasture. Live-stock is indispensable to general farming on this type of soil.

Sheet-washing on the moderate slopes may be prevented to a great extent by the following methods:

(1) By increasing the organic-matter content, thus binding together the soil particles and rendering the soil more porous. This can be done by applying farm manure and plowing under stubble, straw, corn stalks, and legume crops, such as clover and cowpeas.

(2) By deep plowing from seven to ten inches, in order to increase the absorption of water and diminish the run-off. Ten inches of loose soil will readily absorb two inches of rainfall without run-off.

(3) By contour plowing. When land is plowed up and down the slope, as is often done in this state, dead furrows are made which furnish excellent beginnings for gullies. Even the little depressions between furrows aid in washing. On land subject to serious washing, plowing should always be done across the slope, on the contour, so that water will stand in the furrow without running in either direction. Every furrow will then act as an obstruction to the movement of water down the slope, thus checking the velocity of the water

PLATE 7.—GROVE OF LOCUST TREES ABOUT TWENTY-FIVE YEARS OLD ON ROLLING HILL LAND IN JOHNSON COUNTY, ILLINOIS (GROWN BY J. C. B. HEATON)

and its power to wash, and also facilitating absorption and diminishing the amount of run-off.

(4) By using cover crops to hold the soil during the winter and spring. Rye is a fairly good cover crop to sow in the corn during the late summer or early fall. Wheat, especially when seeded late, is a poor crop to grow on rolling land because it does not usually make sufficient growth in the fall to afford a good protection to the soil during winter. Of course both rye and wheat invite the development of chinch bugs. A mixture of winter vetch and clover with a few cowpeas, seeded at the time of the last cultivation of the corn, gives good results in favorable seasons. (See Circular 119, "Washing of Soils and Methods of Prevention.")

This yellow silt loam is markedly acid. Where cropping is practiced, limestone should be used liberally, especially for the benefit of clover grown to provide nitrogen, in which this soil is very deficient, particularly where it has been long cultivated and thus exposed to surface washing. On such land nitrogen is the element which now first limits the growth of grain crops, as will be seen from Plates 8 and 9 and Tables 14 and 15.

In one experiment, a large quantity of the typical worn hill soil was collected from two different places.[1] Each lot of soil was thoroly mixed and put in ten four-gallon jars. Ground limestone was added to all the jars except the first and last in each set, those two being retained as control or check pots. The elements nitrogen, phosphorus, and potassium were added singly and in combination, as shown in Table 14.

As an average, the nitrogen applied produced a yield about eight times as large as that secured without the addition of nitrogen. While some variations in yield are to be expected, because of differences in the individuality of seed

PLATE 8.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND (See Table 14)

TABLE 14.—CROP YIELDS IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND

(Grams per pot)

Pot No.	Soil treatment applied	Wheat	Oats
1	None	3	5
2	Limestone	4	4
3	Limestone, nitrogen	26	45
4	Limestone, phosphorus	3	6
5	Limestone, potassium	3	5
6	Limestone, nitrogen, phosphorus	34	38
7	Limestone, nitrogen, potassium	33	46
8	Limestone, phosphorus, potassium	2	5
9	Limestone, nitrogen, phosphorus, potassium	34	38
10	None	3	5
Average yield with nitrogen		32	42
Average yield without nitrogen		3	5
Average gain for nitrogen		29	37

[1]Soil for wheat pots from loess-covered unglaciated area, and that for oat pots from upper Illinois glaciation.

or other uncontrolled causes, yet there is no doubting the plain lesson taught by these actual trials with growing plants.

The question arises next, Where is the farmer to secure this much-needed nitrogen? To purchase it in commercial fertilizer would cost too much; indeed, under average conditions the cost of the nitrogen in such fertilizers is greater than the value of the increase in crop yields.

There is no need whatever to purchase nitrogen, for the air contains an inexhaustible supply, which, under suitable conditions, the farmer can draw upon, not only without cost, but with profit in the getting. Clover, alfalfa, cowpeas, and soybeans are not only worth raising for their own sake, but they have power to secure nitrogen from the atmosphere if the soil contains limestone and the proper nitrogen-fixing bacteria.

In order to secure further information along this line, another experiment with pot cultures was conducted for several years with the same type of worn hill soil as that used for the wheat cultures described above. The results are reported in Table 15.

To three pots (Nos. 3, 6, and 9) nitrogen was applied in commercial form, at an expense amounting to more than the total value of the crops produced. In three other pots (Nos. 2, 11, and 12) a crop of cowpeas was grown during the late summer and fall and turned under before the wheat or oats were planted. Pots 1 and 8 served for important comparisons. After the second catch crop of cowpeas had been turned under, the yield from Pot 2 exceeded

PLATE 9.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND (See Table 15)

TABLE 15.—CROP YIELDS IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND AND NITROGEN-FIXING GREEN MANURE CROPS

(Grams per pot)

Pot No.	Soil treatment	1903 Wheat	1904 Wheat	1905 Wheat	1906 Wheat	1907 Oats
1	None	5	4	4	4	6
2	Limestone, legume	10	17	26	19	37
11	Limestone, legume, phosphorus	14	19	20	18	27
12	Limestone, legume, phosphorus, potassium	16	20	21	19	30
3	Limestone, nitrogen	17	14	15	9	28
6	Limestone, nitrogen, phosphorus	26	20	18	18	30
9	Limestone, nitrogen, phosphorus, potassium	31	34	21	20	26
8	Limestone, phosphorus, potassium	3	3	5	3	7

that from Pot 3; and in the subsequent years the legume green manures produced, as an average, rather better results than the commercial nitrogen. This experiment confirms that reported in Table 14, in showing the very great need of nitrogen for the improvement of this type of soil; and it also shows that nitrogen need not be purchased, but that it can be obtained from the air by growing legume crops and plowing them under as green manure. Of course the soil can be very markedly improved by feeding the legume crops to live stock and returning the resulting farm manure to the land, if crops of legumes are grown frequently enough and if the farm manure produced is sufficiently abundant and is saved and applied with care.

When this type of soil is to be prepared for seeding down, it may well be treated with five tons per acre of ground limestone, in order to encourage the growth of clover and thus make possible the accumulation of nitrogen, the element in which this type is most deficient wherever it has been long under cultivation. As a rule, it is not advisable to try to enrich this soil in phosphorus, because of the fact that erosion, which is sure to occur to some extent, will renew the supply from the subsoil.

Field experiments covering nine years have been conducted on the yellow silt loam at Vienna, Johnson county. Here heavy applications of ground limestone paid nearly 200 percent on the investment, and about half the limestone applied still remained in the soil for the benefit of later crops. Neither phosphorus nor potassium produced sufficient increase to pay the cost. (The details of these investigations are reported in Soil Report No. 3, "Hardin County Soils.")

One of the most profitable crops to grow on this land is alfalfa. To get alfalfa well started requires a liberal use of limestone, thoro inoculation with nitrogen-fixing bacteria, and a moderate application of farm manure. If manure is not available, it is well to apply about 500 pounds per acre of acid phosphate or steamed bone meal, mix it with the soil, by disking if possible, and then plow it under. The limestone (about 5 tons) should be applied after plowing and mixed with the surface soil in the preparation of the seed bed. The special purpose of this treatment is to give the alfalfa a quick start in order that it may grow rapidly and thus protect the soil from washing.

Light Gray Silt Loam on Tight Clay (332)

Light gray silt loam on tight clay occurs in old timbered regions where the land is so nearly level that there is no chance for rapid surface drainage. It is the most common level timber land of Bond county and occupies a total area of 16.45 square miles (10,528 acres), or 4.42 percent of the county. The type has two distinct phases: one phase is slightly better surface-drained, but lighter colored and less productive; the other is more swampy (water oaks commonly grow on this phase), with a darker surface and a greater porosity, so that better drainage is probably possible. The amount of this latter phase is small as compared with the former and is frequently confined to narrow strips too small to map.

"Scalds" are found on this type, but they are not so common as on the gray silt loam on tight clay (330) or the brown-gray silt loam on tight clay (328).

The surface soil of this type, 0 to 6⅔ inches, is a light gray to almost white silt loam containing 1.6 percent of organic matter, or 16 tons per acre. It is somewhat porous and incoherent, but contains sufficient clay to bake when puddled and dried. When the moisture content is at its optimum, the soil works very well, but because of the low organic-matter content it "runs together" badly with rains or with freezing and thawing when wet. The surface soil, as well as the subsurface and subsoil, contains large numbers of iron oxid concretions of various sizes up to one-fourth inch in diameter. Small pebbles of quartz are sometimes found, possibly having been brought to the surface from the underlying glacial till by burrowing animals during past centuries.

The subsurface varies from light gray silt loam to a white silt, compact but friable, from 2 to 20 inches in thickness. Water passes thru it slowly.

The subsoil consists of a compact yellowish gray clayey silt, or silty clay, only slowly pervious to water, but usually not quite so tight as the corresponding layer of the gray silt loam on tight clay (330). In places the type has a somewhat more friable subsoil which is not so nearly impervious as the subsurface. Where the tight clay occurs at the greater depths from the surface, it is less objectionable.

An invoice of plant food shows great need of nitrogen and phosphorus. With provision made for these, with a liberal use of limestone and organic matter, including legume residues or farm manure, and with proper surface drainage, the soil can be made highly productive.

White Silt Loam on Tight Clay (332.1)

White silt loam on tight clay is found on the level upland, and it is now or was formerly covered by a growth of stunted trees, principally the so-called post oak. The term post-oak flat or post-oak soil is commonly applied to this type, altho these terms are often used locally to designate the poorer phase of light gray silt loam on tight clay (332). The surface drainage is very poor and the subsoil is almost impervious. The total mapped area of this type in the county is only 435 acres, but there are many small areas that cannot be shown on the map. Much of the light-gray silt loam on tight clay (332) grades toward this related type (332.1).

Where land of this type has been cultivated, the surface soil, 0 to 6⅔ inches, is a white silt; in the timbered areas this characteristic white silt is sometimes overlain by an inch or two of dark gray silt loam. The organic-matter content of this layer is even lower in this type than in the light gray silt loam, containing only 1.25 percent, or 12.5 tons per acre. Because of this lack of organic matter and the high silt content, the soil "runs together" badly. Iron oxid concretions are always present.

The subsurface layer is a white silt with many iron oxid concretions. It varies from 4 to 16 inches in thickness and passes abruptly into the subsoil.

The subsoil is a light yellow, iron-stained, silty clay, very tough and plastic when wet and hard when dry, with an organic-matter content of only .30 percent. Both subsurface and subsoil are almost impervious.

The first need of this soil is ground limestone, the initial application of which may well be 4 to 6 tons per acre. The increase in organic matter should follow as rapidly as practicable. Legumes, such as cowpeas, clover, and sweet clover, should be grown and turned under with farm manure and crop residues, such as straw and corn stalks. For such flat, poorly drained land, alsike is usually a more satisfactory crop than red clover. Finally, phosphorus should be used liberally in connection with the organic matter in order to provide a permanent system of soil improvement.

(c) Ridge Soils

Yellow Silt Loam (235)

The morainal ridges of the lower Illinois glaciation have given a slight variation to the usual level topography of this region, their height varying from 20 to 100 feet or more. A fine covering of loess from 5 to 10 feet deep, together with excellent drainage, has resulted in the formation on these ridges of a soil known as yellow silt loam, very different from the surrounding prairie but somewhat resembling in texture the better phase of the yellow silt loam timber land (335) already described. The total area of this type in Bond county is 12.41 square miles (7,942 acres) or 3.33 percent of the county.

The surface soil, 0 to 6⅔ inches, is a yellow or yellowish brown silt loam with a considerable amount of very fine sand. The color varies with the amount of erosion that has taken place. Where little washing has occurred, the color may be a yellowish brown, while with more washing it becomes yellow. The soil is loose, porous, and readily pervious to water. Its physical composition is such as to give it great water-retaining power and strong capillarity, so that it will resist drouth well if properly cultivated. The organic-matter content is about 1.8 percent, or 18 tons per acre.

The subsurface layer, extending from 6⅔ to about 20 inches below the surface, varies from a yellowish brown silt loam to a yellow silt or a slightly clayey silt. It becomes more compact with depth but still retains its perviousness and capillary power.

The upper part of the subsoil is somewhat compact and slightly clayey, but it passes into a friable silt containing some fine sand. It is yellow or reddish yellow in color. Below 24 inches it is sometimes slightly gray or marked with gray blotches, and when grading toward yellow-gray silt loam (334) it becomes decidedly gray in places. This soil, considered from a physical standpoint, is almost as good as could be desired. In respect to aeration, drainage, and ability to withstand drouth, it is one of the best upland types in the county.

The organic-matter content should be increased by growing clovers and cowpeas, and these should be turned under directly or as farm manure, together with crop residues, straw, and corn stalks. The maintenance of organic matter is made more difficult because of the rolling character of the land, which facilitates erosion and the removal of the best soil.

This ridge soil contains no limestone. As a rule the subsoil is markedly acid, but with a liberal use of limestone and thoro inoculation it becomes a very good soil for alfalfa, altho where badly worn manure may well be used in getting the alfalfa started. (See also discussion of yellow silt loam, No. 335.)

Gray-Red Silt Loam on Tight Clay (233)

Gray-red silt loam on tight clay occurs on some of the ridges, which are in part at least of preglacial origin, rising from 5 to 75 feet above the surrounding upland. As a rule, it is one of the poorest upland types in the state, but most of the areas in this county are a better phase of the type than ordinary. This type in Bond county occupies 922 acres. In some places it may suffer from erosion, but it is extremely doubtful whether tile-drainage would profitably benefit this soil,—at best, not until other methods of improvement have been put into practice.

The surface soil is a friable gray silt loam very similar to that of the gray silt loam on tight clay (330).

The subsurface layer also resembles the corresponding stratum in gray silt loam on tight clay both in texture and thickness, but it contains more of the higher oxid of iron, which gives it a reddish color. As a rule, the organic-matter content is low.

The subsoil lies from 7 to 20 inches below the surface and consists of a layer of very plastic, gummy, almost impervious red clay, varying from 4 to 12 inches in thickness and underlain by a less plastic and more silty stratum. When dry, the red clay becomes so hard that it is next to impossible to bore into it with an auger. Where this layer appears at the surface, as it does on some small eroded areas, the land is practically worthless.

This type of soil closely resembles the more extensive gray silt loam on tight clay (330). Methods for its improvement are the same, except on areas subject to considerable erosion, where the addition of phosphorus is not advised. This factor of erosion, together with the tighter texture, as a rule will make the improvement of this type less satisfactory than that of the gray silt loam.

Yellow Fine Sandy Silt Loam (245)

Yellow fine sandy silt loam occupies some of the highest glacial ridges, which have been covered with a deposit of loess varying from 10 to 20 feet in thickness and of slightly coarser grade than the surrounding deposits. The type has always been well drained and as a result is well oxidized. Practically all of it was originally forested. The total area in Bond county is almost 2 square miles (1,267 acres), or .53 percent of the county.

The surface soil, 0 to 6⅔ inches, is a brownish yellow to a yellowish brown silt loam containing from 25 to 35 percent of fine sand. It also contains much coarse silt. This mixture furnishes the basis for an ideal soil. It is easy to work, porous, and at the same time has great water-retaining power and strong capillarity, so that it will resist drouth well when properly cared for. The organic-matter content is about 2 percent, or 20 tons per acre.

The subsurface layer varies from a yellowish brown to a yellow silt loam, containing slightly more clay than the surface soil. It becomes somewhat more compact with depth, but still retains its perviousness and capillary power.

The upper part of the subsoil is a somewhat compact, clayey silt, but it passes into a very pervious friable silt containing considerable amounts of fine sand and coarse silt. It is yellow or reddish yellow in color and rarely contains the gray blotches which are so common in yellow silt loam (235).

From a physical standpoint this type is the best upland soil in the county. As a rule it is low in organic matter and slightly acid. The organic matter should of course be increased, altho the rolling character of the type renders this problem difficult.

Like most soils that are subject to much erosion, this type is poor in nitrogen and rich in potassium. The supply of phosphorus is low but it increases with depth, so that erosion enriches the soil in that constituent. For this reason and also because of the extensive feeding range afforded by the porous character of the soil, the addition of phosphorus is not advised.

Very marked and profitable improvement can be made with the use of limestone and legumes, and these means are sufficient to provide for permanent systems of moderately high production.

(d) BOTTOM-LAND SOILS

Deep Gray Silt Loam (1331)

Deep gray silt loam occurs along most of the streams of the lower Illinois glaciation. It is formed from the gray, yellow-gray, and yellow silt loams that have washed down from the upland and blended into a gray or yellowish gray soil. During floods these lands in most places still receive frequent or occasional deposits of new material. Aside from the difficulties from overflow and lack of drainage, this is the most valuable extensive soil type in Bond county.

This type occupies a total area of 26.22 square miles (16,781 acres), or 7.05 percent of the county. It lies so low that the drainage is generally poor, and there is often much difficulty in getting sufficient outlet for under-drainage or sometimes even for adequate surface drainage. Where a satisfactory outlet can be secured, tile drainage greatly benefits this soil.

The surface soil is a gray silt loam, varying from a gray to a drab in color and from a loam to a clayey silt loam in physical composition.

The subsurface and subsoil are about the same as the surface except that they are lighter in color and commonly a little more clayey with depth. In the smaller stream bottoms, the recent deposits are frequently yellow and slightly sandy, and consequently there is found in places a stratum of yellow on the gray, varying from a few inches to a foot or more in thickness.

In phosphorus content, this type exceeds the most common prairie soil of the corn belt. The porous subsoil affords such a deep feeding range that the application of that element is not likely to give profitable returns, except where overflow is not common and where the soil has been long cropped.

The soil of this type is acid. It is also rather poor in nitrogen, altho this deficiency is counterbalanced to a large extent by the great depth and porosity of the soil.

While the overflow and drainage problems are of first importance, where these are under sufficient control to permit of soil improvement the use of limestone and the addition of nitrogenous organic matter, such as clover or manure plowed under, will make this soil still more productive; and if the land is protected from the usual overflow deposits, the addition of phosphorus will ultimately be necessary; even now it is likely to be profitable for the highest im-

provement of the soil. To illustrate, it may be pointed out that on the University Farm at Urbana, land that has yielded 72.5 bushels of corn per acre as a six-year average, in a rotation of corn, oats, and clover, with limestone and organic manures provided, has with the addition of phosphorus made an average of 88.5 bushels during the same years. Thus there may be room for phosphorus "at the top," even where very satisfactory yields may be secured without its application and where other factors are of first importance.

Deep Brown Silt Loam (1326)

The basic material for the deep brown silt loam naturally belongs to the middle Illinois glaciation with its dark-colored upland soils, but this has been covered by loads of dark sediment brought down by Shoal creek and its tributaries and deposited over their flood plains. This sediment has been more or less mixed with material brought in by small streams from the light-colored upland soils, resulting in the formation of soils intermediate in character or lacking in uniformity. The bottoms along the streams vary in width from a few rods to more than a mile. The soil of the narrower bottoms has a tendency to be darker than that of the wider areas. This type occupies 13.74 square miles (8,794 acres), or 3.7 percent of the area of Bond county. In topography it is flat or with very slight undulations that represent old stream or overflow channels. Better drainage is needed in much of this area.

The surface soil, 0 to 6⅔ inches, is a brown silt loam, varying in places, especially in the flat, poorly drained areas, to a gray silt loam. While the organic-matter content of this type is not high, yet it is more easily maintained here than in the upland because of the occasional overflow and the consequent deposition of material rich in organic matter. The physical composition of this soil varies from a heavy silt loam to a sandy loam, but the areas of these extreme types, especially the latter, are so small and so changeable that it would not mean much to show them on the map, as the next flood might change their boundaries.

The subsurface varies from a brown silt loam to a gray silt loam.

The subsoil varies in color from a brown to a yellowish drab, and in physical composition from a clayey silt to a sandy loam or sometimes even a sand in the lower subsoil.

Under the usual conditions it is very doubtful whether any materials can be applied to this soil with profit, but where feasible some legumes should be grown in the crop rotation.

APPENDIX

A study of the soil map and the tabular statements concerning crop requirements, the plant-food content of the different soil types, and the actual results secured from definite field trials with different methods or systems of soil improvement, and a careful study of the discussion of general principles and of the descriptions of individual soil types, will furnish the most necessary and useful information for the practical improvement and permanent preservation of the productive power of every kind of soil on every farm in the county.

More complete information concerning the most extensive and important soil types in the great soil areas in all parts of Illinois is contained in Bulletin 123, "The Fertility in Illinois Soils," which contains a colored general soil-survey map of the entire state.

Other publications of general interest are:

Bulletin No. 76, "Alfalfa on Illinois Soils"
Bulletin No. 94, "Nitrogen Bacteria and Legumes"
Bulletin No. 115, "Soil Improvement for the Worn Hill Lands of Illinois"
Bulletin No. 125, "Thirty Years of Crop Rotation on the Common Prairie Lands of Illinois"
Circular No. 82, "Physical Improvement of Soils"
Circular No. 110, "Ground Limestone for Acid Soils"
Circular No. 127, "Shall We Use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils?"
Circular No. 129, "The Use of Commercial Fertilizers"
Circular No. 149, "Results of Scientific Soil Treatment" and "Methods and Results of Ten Years' Soil Investigation in Illinois"
Circular No. 165, "Shall We Use 'Complete' Commercial Fertilizers in the Corn Belt?"
Circular No. 167, "The Illinois System of Permanent Fertility"

NOTE.—Information as to where to obtain limestone, phosphate, bone meal, and potassium salts, methods of application, etc., will also be found in Circulars 110 and 165.

SOIL SURVEY METHODS

The detail soil survey of a county consists essentially of ascertaining, and indicating on a map, the location and extent of the different soil types; and, since the value of the survey depends upon its accuracy, every reasonable means is employed to make it trustworthy. To accomplish this object three things are essential: first, careful, well-trained men to do the work; second, an accurate base map upon which to show the results of the work; and, third, the means necessary to enable the men to place the soil-type boundaries, streams, etc., accurately upon the map.

The men selected for the work must be able to keep their location exactly and to recognize the different soil types, with their principal variations and limits, and they must show these upon the maps correctly. A definite system is employed in checking up this work. As an illustration, one soil expert will survey and map a strip 80 rods or 160 rods wide and any convenient length, while his associate will work independently on another strip adjoining this area, and, if the work is correctly done, the soil type boundaries must match up on the line between the two strips.

An accurate base map for field use is absolutely necessary for soil mapping. The base maps are made on a scale of one inch to the mile. The official data of the original or subsequent land survey are used as a basis in the construction of these maps, while the most trustworthy county map available is used in

locating temporarily the streams, roads, and railroads. Since the best of these published maps have some inaccuracies, the location of every road, stream, and railroad must be verified by the soil surveyors, and corrected if wrongly located. In order to make these verifications and corrections, each survey party is provided with an odometer for measuring distances, and a plane table for determining directions of angling roads, railroads, etc.

Each surveyor is provided with a base map of the proper scale, which is carried with him in the field; and the soil-type boundaries, ditches, streams, and necessary corrections are placed in their proper locations upon the map while the mapper is on the area. Each section, or square mile, is divided into 40-acre plots on the map, and the surveyor must inspect every ten acres and determine the type or types of soil composing it. The different types are indicated on the map by different colors, pencils for this purpose being carried in the field.

A small auger 40 inches long forms for each man an invaluable tool with which he can quickly secure samples of the different strata for inspection. An extension for making the auger 80 inches long is carried by each party, so that any peculiarity of the deeper subsoil layers may be studied. Each man carries a compass to aid in keeping directions. Distances along roads are measured by an odometer attached to the axle of the vehicle, while distances in the field off the roads are determined by pacing, an art in which the men become expert by practice. The soil boundaries can thus be located with as high a degree of accuracy as can be indicated by pencil on the scale of one inch to the mile.

SOIL CHARACTERISTICS

The unit in the soil survey is the soil type, and each type possesses more or less definite characteristics. The line of separation between adjoining types is usually distinct, but sometimes one type grades into another so gradually that it is very difficult to draw the line between them. In such exceptional cases, some slight variation in the location of soil-type boundaries is unavoidable.

Several factors must be taken into account in establishing soil types. These are (1) the geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial, or cumulose; (2) the topography, or lay of the land; (3) the native vegetation, as forest or prairie grasses; (4) the structure, or the depth and character of the surface, subsurface, and subsoil; (5) the physical, or mechanical, composition of the different strata composing the soil, as the percentages of gravel, sand, silt, clay, and organic matter which they contain; (6) the texture, or porosity, granulation, friability, plasticity, etc.; (7) the color of the strata; (8) the natural drainage; (9) the agricultural value, based upon its natural productiveness; (10) the ultimate chemical composition and reaction.

The common soil constituents are indicated in the following outline:

Soil constituents	Organic matter	Comprising undecomposed and partially decayed vegetable or organic material	
	Inorganic matter	Clay	.001 mm.[1] and less
		Silt	.001 mm. to .03 mm.
		Sands	.03 mm. to 1. mm.
		Gravel	1. mm. to 32 mm.
		Stones	32. mm. and over

Further discussion of these constituents is given in Circular 82.

[1]25 millimeters equal 1 inch.

GROUPS OF SOIL TYPES

The following gives the different general groups of soils:

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or silt.

Peaty loams—15 to 35 percent of organic matter mixed with much sand. Some silt and a little clay may be present.

Mucks—15 to 35 percent of partly decomposed organic matter mixed with much clay and silt.

Clays—Soils with more than 25 percent of clay, usually mixed with much silt.

Clay loams—Soils with from 15 to 25 percent of clay, usually mixed with much silt and some sand.

Silt loams—Soils with more than 50 percent of silt and less than 15 percent of clay, mixed with some sand.

Loams—Soils with from 30 to 50 percent of sand mixed with much silt and a little clay.

Sandy loams—Soils with from 50 to 75 percent of sand.

Fine sandy loams—Soils with from 50 to 75 percent of fine sand mixed with much silt and little clay.

Sands—Soils with more than 75 percent of sand.

Gravelly loams—Soils with 25 to 50 percent of gravel with much sand and some silt.

Gravels—Soils with more than 50 percent of gravel and much sand.

Stony loams—Soils containing a considerable number of stones over one inch in diameter.

Rock outcrop—Usually ledges of rock having no direct agricultural value.

More or less organic matter is found in all the above groups.

SUPPLY AND LIBERATION OF PLANT FOOD

The productive capacity of land in humid sections depends almost wholly upon the power of the soil to feed the crop; and this, in turn, depends both upon the stock of plant food contained in the soil and upon the rate at which it is liberated, or rendered soluble and available for use in plant growth. Protection from weeds, insects, and fungous diseases, tho exceedingly important, is not a positive but a negative factor in crop production.

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but the rate of liberation is governed by many factors, some of which may be controlled by the farmer, while others are largely beyond his control. Chief among the important controllable factors which influence the liberation of plant food are limestone and decaying organic matter, which may be added to the soil by direct application of ground limestone and farm manure. Organic matter may be supplied also by green-manure crops and crop residues, such as clover, cowpeas, straw, and corn stalks. The rate of decay of organic matter depends largely upon its age and origin,

and it may be hastened by tillage. The chemical analysis shows correctly the total organic carbon, which represents, as a rule, but little more than half the organic matter; so that 20,000 pounds of organic carbon in the plowed soil of an acre correspond to nearly 20 tons of organic matter. But this organic matter consists largely of the old organic residues that have accumulated during the past centuries because they were resistant to decay, and 2 tons of clover or cowpeas plowed under may have greater power to liberate plant food than the 20 tons of old, inactive organic matter. The recent history of the individual farm or field must be depended upon for information concerning recent additions of active organic matter, whether in applications of farm manure, in legume crops, or in grass-root sods of old pastures.

Probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that with the normal rainfall of Illinois the productive power of the land depends primarily upon the stock of plant food contained in the soil and upon the rate at which it is liberated, just as the success of the merchant depends primarily upon his stock of goods and the rapidity of sales. In both cases the stock of any commodity must be increased or renewed whenever the supply of such commodity becomes so depleted as to limit the success of the business, whether on the farm or in the store.

As the organic matter decays, certain decomposition products are formed, including much carbonic acid, some nitric acid, and various organic acids, and these have power to act upon the soil and dissolve the essential mineral plant foods, thus furnishing soluble phosphates, nitrates, and other salts of potassium, magnesium, calcium, etc., for the use of the growing crop.

As already explained, fresh organic matter decomposes much more rapidly than old humus, which represents the organic residues most resistant to decay and which consequently has accumulated in the soil during the past centuries. The decay of this old humus can be hastened both by tillage, which maintains a porus condition and thus permits the oxygen of the air to enter the soil more freely and to effect the more rapid oxidation of the organic matter, and also by incorporating with the old, resistant residues some fresh organic matter, such as farm manure, clover roots, etc., which decay rapidly and thus furnish or liberate organic matter and inorganic food for bacteria, the bacteria, under such favorable conditions, appearing to have power to attack and decompose the old humus. It is probably for this reason that peat, a very inactive and inefficient fertilizer when used by itself, becomes much more effective when composted with fresh farm manure; so that two tons of the compost[1] may be worth as much as two tons of manure, but if applied separately, the peat has little value. Bacterial action is also promoted by the presence of limestone.

[1]In his book, "Fertilizers," published in 1839, Cuthbert W. Johnson reported such compost to have been much used in England and to be valued as highly, "weight for weight, as farm-yard dung."

The condition of the organic matter of the soil is indicated more or less definitely by the ratio of carbon to nitrogen. As an average, the fresh organic matter incorporated with soils contains about twenty times as much carbon as nitrogen, but the carbohydrates ferment and decompose much more rapidly than the nitrogenous matter; and the old resistant organic residues, such as are found in normal subsoils, commonly contain only five or six times as much carbon as nitrogen. Soils of normal physical composition, such as loam, clay loam, silt loam, and fine sandy loam, when in good productive condition, contain about twelve to fourteen times as much carbon as nitrogen in the surface soil; while in old, worn soils that are greatly in need of fresh, active, organic manures, the ratio is narrower, sometimes falling below ten of carbon to one of nitrogen. Soils of cut-over or burnt-over timber lands sometimes contain so much partially decayed wood or charcoal as to destroy the value of the nitrogen-carbon ratio for the purpose indicated. (Except in newly made alluvial soils, the ratio is usually narrower in the subsurface and subsoil than in the surface stratum.)

It should be kept in mind that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all agricultural plants, only one (hydrogen) from water, and seven from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes), in case the amount liberated from the soil is insufficient; but even these plants (which include only the clovers, peas, beans, and vetches, among our common agricultural plants) secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron, and sulfur), and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Plants are made of plant-food elements in just the same sense that a building is made of wood and iron, brick, stone, and mortar. Without materials, nothing material can be made. The normal temperature, sunshine, rainfall, and length of season in central Illinois are sufficient to produce 50 bushels of wheat per acre, 100 bushels of corn, 100 bushels of oats, and 4 tons of clover hay; and, where the land is properly drained and properly tilled, such crops would frequently be secured *if the plant foods were present in sufficient amounts and liberated at a sufficiently rapid rate to meet the absolute needs of the crops.*

CROP REQUIREMENTS

The accompanying table shows the requirements of wheat, corn, oats, and clover for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally in sufficient abundance compared with the amounts needed by plants, so that they are never known to limit the yield of general farm crops grown under normal conditions.)

TABLE A.—PLANT FOOD IN WHEAT, CORN, OATS, AND CLOVER

Produce		Nitrogen	Phosphorus	Potassium	Magnesium	Calcium
Kind	Amount					
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Wheat, grain........	50 bu.	71	12	13	4	1
Wheat straw........	2½ tons	25	4	45	4	10
Corn, grain..........	100 bu.	100	17	19	7	1
Corn stover..........	3 tons	48	6	52	10	21
Corn cobs...........	½ ton	2		2		
Oats, grain..........	100 bu.	66	11	16	4	2
Oat straw..........	2½ tons	31	5	52	7	15
Clover seed.........	4 bu.	7	2	3	1	1
Clover hay.........	4 tons	160	20	120	31	117
Total in grain and seed....................		244[1]	42	51	16	4
Total in four crops........................		510[1]	77	322	68	168

[1]These amounts include the nitrogen contained in the clover seed or hay, which, however, may be secured from the air.

To be sure, these are large yields, but shall we try to make possible the production of yields only half or a quarter as large as these, or shall we set as our ideal this higher mark, and then approach it as nearly as possible with profit? Among the four crops, corn is the largest, with a total yield of more than six tons per acre; and yet the 100-bushel crop of corn is often produced on rich pieces of land in good seasons. In very practical and profitable systems of farming, the Illinois Experiment Station has produced, as an average of the six years 1905 to 1910, a yield of 87 bushels of corn per acre in grain farming (with limestone and phosphorus applied, and with crop residues and legume crops turned under), and 90 bushels per acre in live-stock farming (with limestone, phosphorus, and manure).

The importance of maintaining a rich surface soil cannot be too strongly emphasized. This is well illustrated by data from the Rothamsted Experiment Station, the oldest in the world. On Broadbalk field, where wheat has been grown since 1844, the average yields for the ten years 1892 to 1901 were 12.3 bushels per acre on Plot 3 (unfertilized) and 31.8 bushels on Plot 7 (well fertilized), but the amounts of both nitrogen and phosphorus in the subsoil (9 to 27 inches) were distinctly greater in Plot 3 than in Plot 7, thus showing that the higher yields from Plot 7 were due to the fact that the plowed soil had been enriched. In 1893 Plot 7 contained per acre in the surface soil (0 to 9 inches) about 600 pounds more nitrogen and 900 pounds more phosphorus than Plot 3. Even a rich subsoil has little value if it lies beneath a worn-out surface.

METHODS OF LIBERATING PLANT FOOD

Limestone and decaying organic matter are the principal materials which the farmer can utilize most profitably to bring about the liberation of plant food. The limestone corrects the acidity of the soil and thus encourages the development not only of the nitrogen-gathering bacteria which live in the nodules on the roots of clover, cowpeas, and other legumes, but also the nitrifying bacteria, which have power to transform the insoluble and unavailable organic

nitrogen into soluble and available nitrate nitrogen. At the same time, the products of this decomposition have power to dissolve the minerals contained in the soil, such as potassium and magnesium, and also to dissolve the insoluble phosphate and limestone which may be applied in low-priced forms.

Tillage, or cultivation, also hastens the liberation of plant food by permitting the air to enter the soil and burn out the organic matter; but it should never be forgotten that tillage is wholly destructive, that it adds nothing whatever to the soil, but always leaves it poorer. Tillage should be practiced so far as is necessary to prepare a suitable seed-bed for root development and also for the purpose of killing weeds, but more than this is unnecessary and unprofitable in seasons of normal rainfall; and it is much better actually to enrich the soil by proper applications or additions, including limestone and organic matter (both of which have power to improve the physical condition as well as to liberate plant food) than merely to hasten soil depletion by means of excessive cultivation.

PERMANENT SOIL IMPROVEMENT

The best and most profitable methods for the permanent improvement of the common soils of Illinois are as follows:

(1) If the soil is acid, apply at least two tons per acre of ground limestone, preferably at times magnesian limestone ($CaCO_3MgCO_3$), which contains both calcium and magnesium and has slightly greater power to correct soil acidity, ton for ton, than the ordinary calcium limestone ($CaCO_3$); and continue to apply about two tons per acre of ground limestone every four or five years. On strongly acid soils, or on land being prepared for alfalfa, five tons per acre of ground limestone may well be used for the first application.

(2) Adopt a good rotation of crops, including a liberal use of legumes, and increase the organic matter of the soil either by plowing under the legume crops and other crop residues (straw and corn stalks), or by using for feed and bedding practically all the crops raised and returning the manure to the land with the least possible loss. No one can say in advance what will prove to be the best rotation of crops, because of variation in farms and farmers, and in prices for produce, but the following are suggested to serve as models or outlines:

First year, corn.
Second year, corn.
Third year, wheat or oats (with clover or clover and grass).
Fourth year, clover or clover and grass.
Fifth year, wheat and clover or grass and clover.
Sixth year, clover or clover and grass.

Of course there should be as many fields as there are years in the rotation. In grain farming, with small grain grown the third and fifth years, most of the coarse products should be returned to the soil, and the clover may be clipped and left on the land (only the clover seed being sold the fourth and sixth years); or, in live-stock farming, the field may be used three years for timothy and clover pasture and meadow if desired. The system may be reduced to a five-year rotation by cutting out either the second or the sixth year, and to a four-year system by omitting the fifth and sixth years.

With two years of corn, followed by oats with clover-seeding the third year, and by clover the fourth year, all produce can be used for feed and bedding if other land is available for permanent pasture. Alfalfa may be grown on a fifth field for four or eight years, which is to be alternated with one of the four; or the alfalfa may be moved every five years, and thus rotated over all five fields every twenty-five years.

Other four-year rotations more suitable for grain farming are:

Wheat (and clover), corn, oats, and clover; or corn (and clover), cowpeas, wheat, and clover. (Alfalfa may be grown on a fifth field and rotated every five years, the hay being sold.)

Good three-year rotations are:

Corn, oats, and clover; corn, wheat, and clover; or wheat (and clover), corn (and clover), and cowpeas, in which two cover crops and one regular crop of legumes are grown in three years.

A five-year rotation of (1) corn (and clover), (2) cowpeas, (3) wheat, (4) clover, and (5) wheat (and clover) allows legumes to be seeded four times. Alfalfa may be grown on a sixth field for five or six years in the combination rotation, alternating between two fields every five years, or rotating over all the fields if moved every six years.

To avoid clover sickness it may sometimes be necessary to substitute sweet clover or alsike for red clover in about every third rotation, and at the same time to discontinue its use in the cover-crop mixture. If the corn crop is not too rank, cowpeas or soybeans may also be used as a cover crop (seeded at the last cultivation) in the southern part of the state, and, if necessary to avoid disease, these may well alternate in successive rotations.

For easy figuring it may well be kept in mind that the following amounts of nitrogen are required for the produce named:

1 bushel of oats (grain and straw) requires 1 pound of nitrogen.
1 bushel of corn (grain and stalks) requires 1½ pounds of nitrogen.
1 bushel of wheat (grain and straw) requires 2 pounds of nitrogen.
1 ton of timothy requires 24 pounds of nitrogen.
1 ton of clover contains 40 pounds of nitrogen.
1 ton of cowpeas contains 43 pounds of nitrogen.
1 ton of average manure contains 10 pounds of nitrogen.

The roots of clover contain about half as much nitrogen as the tops, and the roots of cowpeas contain about one-tenth as much as the tops.

Soils of moderate productive power will furnish as much nitrogen to clover (and two or three times as much to cowpeas) as will be left in the roots and stubble. In grain crops, such as wheat, corn, and oats, about two-thirds of the nitrogen is contained in the grain and one-third in the straw or stalks. (See also discussion of "The Potassium Problem," on pages following.)

(3) On all lands deficient in phosphorus (except on those susceptible to serious erosion by surface washing or gullying) apply that element in considerably larger amounts than are required to meet the actual needs of the crops desired to be produced. The abundant information thus far secured shows positively that fine-ground natural rock phosphate can be used successfully and very profitably, and clearly indicates that this material will be the most economical form of phosphorus to use in all ordinary systems of permanent, profitable soil

improvement. The first application may well be one ton per acre, and subsequently about one-half ton per acre every four or five years should be applied, at least until the phosphorus content of the plowed soil reaches 2,000 pounds per acre, which may require a total application of from three to five or six tons per acre of raw phosphate containing 12½ percent of the element phosphorus.

Steamed bone meal and even acid phosphate may be used in emergencies, but it should always be kept in mind that phosphorus delivered in Illinois costs about 3 cents a pound in raw phosphate (direct from the mine in carload lots), but 10 cents a pound in steamed bone meal, and about 12 cents a pound in acid phosphate, both of which cost too much per ton to permit their common purchase by farmers in carload lots, which is not the case with limestone or raw phosphate.

Phosphorus once applied to the soil remains in it until removed in crops, unless carried away mechanically by soil erosion. (The loss by leaching is only about 1½ pounds per acre per annum, so that more than 150 years would be required to leach away the phosphorus applied in one ton of raw phosphate.)

The phosphate and limestone may be applied at any time during the rotation, but a good method is to apply the limestone after plowing and work it into the surface soil in preparing the seed bed for wheat, oats, rye, or barley, where clover is to be seeded; while phosphate is best plowed under with farm manure, clover, or other green manures, which serve to liberate the phosphorus.

(4) Until the supply of decaying organic matter has been made adequate, on the poorer types of upland timber and gray prairie soils some temporary benefit may be derived from the use of a soluble salt or a mixture of salts, such as kainit, which contains both potassium and magnesium in soluble form and also some common salt (sodium chlorid). About 600 pounds per acre of kainit applied and turned under with the raw phosphate will help to dissolve the phosphorus as well as to furnish available potassium and magnesium, and for a few years such use of kainit may be profitable on lands deficient in organic matter, but the evidence thus far secured indicates that its use is not absolutely necessary and that it will not be profitable after adequate provision is made for supplying decaying organic matter, since this will necessitate returning to the soil the potassium contained in the crop residues from grain farming or the manure produced in live-stock farming, and will also provide for the liberating of potassium from the soil. (Where hay or straw is sold, manure should be bought.)

On soils which are subject to surface washing, including especially the yellow silt loam of the upland timber area, and to some extent the yellow-gray silt loam and other more rolling areas, the supply of minerals in the subsurface and subsoil (which gradually renew the surface soil) tends to provide for a low-grade system of permanent agriculture if some use is made of legume plants, as in long rotations with much pasture, because both the minerals and nitrogen are thus provided in some amount almost permanently; but where such lands are farmed under such a system, not more than two or three grain crops should be grown during a period of ten or twelve years, the land being kept in pasture most of the time; and where the soil is acid a liberal use of limestone, as topdressings if necessary, and occasional reseeding with clovers will benefit both the pasture and indirectly the grain crops.

ADVANTAGE OF CROP ROTATION AND PERMANENT SYSTEMS

It should be noted that clover is not likely to be well infected with the clover bacteria during the first rotation on a given farm or field where it has not been grown before within recent years; but even a partial stand of clover the first time will probably provide a thousand times as many bacteria for the next clover crop as one could afford to apply in artificial inoculation, for a single root-tubercle may contain a million bacteria developed from one during the season's growth.

This is only one of several advantages of the second course of the rotation over the first course. Thus the mere practice of crop rotation is an advantage, especially in helping to rid the land of insects and foul grass and weeds. The clover crop is an advantage to subsequent crops because of its deep-rooting characteristic. The larger applications of organic manures (made possible by the larger crops) are a great advantage; and in systems of permanent soil improvement, such as are here advised and illustrated, more limestone and more phosphorus are provided than are needed for the meager or moderate crops produced during the first rotation, and consequently the crops in the second rotation have the advantage of such accumulated residues (well incorporated with the plowed soil) in addition to the regular applications made during the second rotation.

This means that these systems tend positively toward the making of richer lands. The ultimate analyses recorded in the tables give the absolute invoice of these Illinois soils. They show that most of them are positively deficient only in limestone, phosphorus, and nitrogenous organic matter; and the accumulated information from careful and long-continued investigations in different parts of the United States clearly establishes the fact that in general farming these essentials can be supplied with greatest economy and profit by the use of ground natural limestone, very finely ground natural rock phosphate, and legume crops to be plowed under directly or in farm manure. On normal soils no other applications are absolutely necessary, but, as already explained, the addition of some soluble salt in the beginning of a system of improvement on some of these soils produces temporary benefit, and if some inexpensive salt, such as kainit, is used, it may produce sufficient increase to more than pay the added cost.

THE POTASSIUM PROBLEM

As reported in Illinois Bulletin 123, where wheat has been grown every year for more than half a century at Rothamsted, England, exactly the same increase was produced (5.6 bushels per acre), as an average of the first 24 years, whether potassium, magnesium, or sodium was applied, the rate of application per annum being 200 pounds of potassium sulfate and molecular equivalents of magnesium sulfate and sodium sulfate. As an average of 60 years (1852 to 1911), the yield of wheat was 12.7 bushels on untreated land and 23.3 bushels where 86 pounds of nitrogen and 29 pounds of phosphorus per acre per annum were applied. As further additions, 85 pounds of potassium raised the yield to 31.3 bushels; 52 pounds of magnesium raised it to 29.2 bushels; and 50 pounds of sodium raised it to 29.5 bushels. Where potassium was applied, the wheat crop removed an-

nually an average of 40 pounds of that element in the grain and straw, or three times as much as would be removed in the grain only for such crops as are suggested in Table A. The Rothamsted soil contained an abundance of limestone, but no organic matter was provided except the little in the stubble and roots of the wheat plants.

On another field at Rothamsted the average yield of barley for 60 years (1852 to 1911) was 14.2 bushels on untreated land, 38.1 bushels where 43 pounds of nitrogen and 29 pounds of phosphorus were applied per acre per annum; while the further addition of 85 pounds of potassium, 19 pounds of magnesium, and 14 pounds of sodium (all in sulfates) raised the average yield to 41.5 bushels. Where only 70 pounds of sodium were applied in addition to the nitrogen and phosphorus, the average was 43.0 bushels. Thus, as an average of 60 years, the use of sodium produced 1.8 bushels less wheat and 1.5 bushels more barley than the use of potassium, with both grain and straw removed and no organic manures returned.

In recent years the effect of potassium is becoming much more marked than that of sodium or magnesium, on the wheat crop; but this must be expected to occur in time where no potassium is returned in straw or manure, and no provision made for liberating potassium from the supply still remaining in the soil. If the wheat straw, which contains more than three-fourths of the potassium removed in the wheat crop (see Table A), were returned to the soil, the necessity of purchasing potassium in a good system of farming on such land would be at least very remote, for the supply would be adequately maintained by the actual amount returned in the straw, together with the additional amount which would be liberated from the soil by the action of decomposition products.

While about half the potassium, nitrogen, and organic matter, and about one-fourth the phosphorus contained in manure is lost by three or four months' exposure in the ordinary pile in the barn yard, there is practically no loss if plenty of absorbent bedding is used on cement floors, and if the manure is hauled to the field and spread within a day or two after it is produced. Again, while in average live-stock farming the animals destroy two-thirds of the organic matter and retain one-fourth of the nitrogen and phosphorus from the food they consume, they retain less than one-tenth of the potassium; so that the actual loss of potassium in the products sold from the farm, either in grain farming or in live-stock farming, is wholly negligible on land containing 25,000 pounds or more of potassium in the surface 6⅔ inches.

The removal of one inch of soil per century by surface washing (which is likely to occur wherever there is satisfactory surface drainage and frequent cultivation) will permanently maintain the potassium in grain farming by renewal from the subsoil, provided one-third of the potassium is removed by cropping before the soil is carried away.

From all these facts it will be seen that the potassium problem is not one of addition but of liberation; and the Rothamsted records show that for many years other soluble salts have practically the same power as potassium to increase crop yields in the absence of sufficient decaying organic matter. Whether this

action relates to supplying or liberating potassium for its own sake, or to the power of the soluble salt to increase the availability of phosphorus or other elements, is not known, but where much potassium is removed, as in the entire crops at Rothamsted, with no return of organic residues, probably the soluble salt functions in both ways.

As an average of 112 separate tests conducted in 1907, 1908, 1909, and 1910 on the Fairfield experiment field, an application of 200 pounds of potassium sulfate, containing 85 pounds of potassium and costing $5.10, increased the yield of corn by 9.3 bushels per acre; while 600 pounds of kainit, containing only 60 pounds of potassium and costing $4, gave an increase of 10.7 bushels. Thus, at 40 cents a bushel for corn, the kainit paid for itself; but these results, like those at Rothamsted, were secured where no adequate provision had been made for decaying organic matter.

Additional experiments at Fairfield included an equally complete test with potassium sulfate and kainit on land to which 8 tons per acre of farm manure were applied. As an average of 112 tests with each material, the 200 pounds of potassium sulfate increased the yield of corn by 1.7 bushels, while the 600 pounds of kainit also gave an increase of 1.7 bushels. Thus, where organic manure was supplied, very little effect was produced by the addition of either potassium sulfate or kainit; in part perhaps because the potassium removed in the crops is mostly returned in the manure if properly cared for, and perhaps in larger part because the decaying organic matter helps to liberate and hold in solution other plant-food elements, especially phosphorus.

In laboratory experiments at the Illinois Experiment Station, it has been shown by chemical analysis that potassium salts and most other soluble salts increase the solubility of the phosphorus in soil and in rock phosphate; also that the addition of glucose with rock phosphate in pot-culture experiments increases the availability of the phosphorus, as measured by plant growth, altho the glucose consists only of carbon, hydrogen, and oxygen, and thus contains no plant food of value.

If we remember that, as an average, live stock destroy two-thirds of the organic matter of the food they consume, it it easy to determine from Table A that more organic matter will be supplied in a proper grain system than in a strictly live-stock system; and the evidence thus far secured from older experiments at the University and at other places in the state indicates that if the corn stalks, straw, clover, etc., are incorporated with the soil as soon as practicable after they are produced (which can usually be done in the late fall or early spring), there is little or no difficulty in securing sufficient decomposition in our humid climate to avoid serious interference with the capillary movement of the soil moisture, a common danger from plowing under too much coarse manure of any kind in the late spring of a dry year.

If, however, the entire produce of the land is sold from the farm, as in hay farming or when both grain and straw are sold, of course the draft on potassium will then be so great that in time it must be renewed by some sort of application. As a rule, farmers following this practice ought to secure manure from town, since they furnish the bulk of the material out of which manure is produced.

CALCIUM AND MAGNESIUM

When measured by the actual crop requirements for plant food, magnesium and calcium are more limited in some Illinois soils than potassium. But with these elements we must also consider the loss by leaching. As an average of 90 analyses[1] of Illinois well-waters drawn chiefly from glacial sands, gravels, or till, 3 million pounds of water (about the average annual drainage per acre for Illinois) contained 11 pounds of potassium, 130 of magnesium, and 330 of calcium. These figures are very significant, and it may be stated that if the plowed soil is well supplied with the carbonates of magnesium and calcium, then a very considerable proportion of these amounts will be leached from that stratum. Thus the loss of calcium from the plowed soil of an acre at Rothamsted, England, where the soil contains plenty of limestone, has averaged more than 300 pounds a year as determined by analyzing the soil in 1865 and again in 1905. Practically the same amount of calcium was found, by analyses, in the Rothamsted drainage waters.

Common limestone, which is calcium carbonate ($CaCO_3$), contains, when pure, 40 percent of calcium, so that 800 pounds of limestone are equivalent to 320 pounds of calcium. Where 10 tons per acre of ground limestone were applied at Edgewood, Illinois, the average annual loss during the next ten years amounted to 790 pounds per acre. The definite data from careful investigations seem to be ample to justify the conclusion that where limestone is needed at least 2 tons per acre should be applied every 4 or 5 years.

It is of interest to note that thirty crops of clover of four tons each would require 3,510 pounds of calcium, while the most common prairie land of southern Illinois contains only 3,420 pounds of total calcium in the plowed soil of an acre. (See Soil Report No. 1.) Thus limestone has a positive value on some soils for the plant food which it supplies, in addition to its value in correcting soil acidity and in improving the physical condition of the soil. Ordinary limestone (abundant in the southern and western parts of the state) contains nearly 800 pounds of calcium per ton; while a good grade of dolomitic limestone (the more common limestone of northern Illinois) contains about 400 pounds of calcium and 300 pounds of magnesium per ton. Both of these elements are furnished in readily available form in ground dolomitic limestone.

[1]Reported by Doctor Bartow and associates, of the Illinois State Water Survey.

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

SOIL REPORT NO. 9

LAKE COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER,
E. VAN ALSTINE, and F. W. GARRETT

URBANA, ILLINOIS, APRIL, 1915

INTRODUCTORY NOTE

About two-thirds of Illinois lies in the corn belt, where most of the prairie lands are black or dark brown in color. In the southern third of the state, the prairie soils are largely of a gray color. This region is better known as the wheat belt, altho wheat is often grown in the corn belt and corn is also a common crop in the wheat belt.

Moultrie county, representing the corn belt; Clay county, which is fairly representative of the wheat belt; and Hardin county, which is taken to represent the unglaciated area of the extreme southern part of the state, were selected for the first Illinois Soil Reports by counties. While these three county soil reports were sent to the Station's entire mailing list within the state, subsequent reports are sent only to those on the mailing list who are residents of the county concerned, and to any one else upon request.

Each county report is intended to be as nearly complete in itself as it is practicable to make it, and, even at the expense of some repetition, each will contain a general discussion of important fundamental principles in order to help the farmer and landowner understand the meaning of the soil fertility invoice for the lands in which he is interested. In Soil Report No. 1, "Clay County Soils," this discussion serves in part as an introduction, while in this and other reports, it will be found in the Appendix; but if necessary it should be read and studied in advance of the report proper.

LAKE COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER, E. VAN ALSTINE, AND F. W. GARRETT

Lake county is located in the northeast corner of Illinois in the late Wisconsin glaciation, and is covered with a deposit of material made by the Lake Michigan glacier during its two stages. The topography of the county, tho quite rolling in many parts, is due almost entirely to the very irregular deposition of material by this glacier. Two distinct morainal areas occur. The one known as the Lake Border morainic system occupies the eastern part of the county and extends southward in the form of two low ridges, one near the lake and another just east of the Des Plaines river; the other, the Valparaiso morainic system, occupies the western part of the county. The latter reaches an altitude of about 300 feet above Lake Michigan. These morainic areas are marked by large numbers of kettle-holes, or basin-like depressions, that in the most rolling parts sometimes have a depth of 75 feet. Numerous lakes are found in the Valparaiso morainic system.

The drift deposited by the Lake Michigan glacier over the county has a minimum depth of probably 150 feet, while the thicker deposits are between 300 and 400 feet. Leverett, in Monograph 38 of the United States Geological Survey, states that the deposit of drift averages more than 200 feet in thickness over the county. Borings indicate the presence of still older glacial drift beneath that of the late Wisconsin.

Physiography

Lake county is divided into two distinct drainage systems—one sloping into Lake Michigan and comprizing probably not more than one-fifteenth of the total area of the county, and a second, drained by the Des Plaines and the Fox rivers, into the Illinois. The large number of lakes and swamps in this county indicate very late drainage systems, so late that practically all of the lowland is occupied either by lakes or by swamps. The streams have not had time to form valleys sufficiently deep for draining these low areas. There are about fifty lakes in the county large enough to be shown on the soil map, many of which are surrounded, or nearly so, by swamps containing deposits of peat.

The altitudes of some places in the county above sea level are as follows: Antioch, 770 feet; Aptakisic, 682; Diamond Lake, 760; Fox Lake, 745; Gilmer, 810; Gray's Lake, 799; Gurnee, 677; Highland Park, 691; Lake Bluff, 683; Lake Villa, 796; Lake Zurich, 873; Leithton, 723; Libertyville, 670; Loon Lake, 783; Prairie View, 694; Rodont, 676; Russell, 677; Volo, 890; Wadsworth, 673; War-

renton, 710; Waukegan (C. & N. W.), 596. A bench mark on the east entrance of the courthouse at Waukegan is 668.4 feet. The mean altitude of the water of Lake Michigan is 581 feet above sea level.

SOIL MATERIAL AND SOIL TYPES

The Lake Michigan glacier left a deposit of boulder clay (a mixture of boulders, gravel, sand, silt, and clay), which has been transformed into soil in some places; but the larger part of the county subsequently received a shallow deposit of 12 to 40 inches of loessial material formed from the fine rock flour produced by the grinding action of the glacier. This has been reworked by the wind and water and now covers the level and less rolling areas to an average depth of 16 to 20 inches. Beneath this is often found a stratum a few inches in thickness which contains a great many gravel, indicating the washing out of the fine material before the loess was deposited. From Waukegan to the state line a deposit has been formed by Lake Chicago which consists of a series of sand ridges only a few rods apart that have very little argricultural use. Between these ridges peat deposits are frequently found.

TABLE 1.—SOIL TYPES OF LAKE COUNTY

Soil type No.	Name of type	Area in square miles	Area in acres	Percent of total area
	(a) Upland Prairie Soils (page 23)			
1026 / 1226	Brown silt loam	137.50	88 001	28.48
1060 / 1260	Brown sandy loam	2.88	1 844	.60
	(b) Upland Timber Soils (page 25)			
1034 / 1234	Yellow-gray silt loam	196.01	125 447	40.59
1035 / 1235	Yellow silt loam	38.50	24 639	7.98
1064	Yellow-gray sandy loam	.76	488	.16
1064.4	Yellow-gray sandy loam on gravel	1.48	944	.30
1081 / 1281	Dune sand	1.47	938	.30
1090 / 1290	Gravelly loam	.96	611	.20
	(c) Terrace Soils (page 30)			
1527	Brown silt loam over gravel	1.85	1 184	.38
1564.4	Yellow-gray sandy loam on gravel	2.25	1 440	.47
1560.4	Brown sandy loam on gravel	2.40	1 539	:50
1590.4	Gravelly loam on gravel	.28	179	.06
	(d) Swamp and Bottom-Land Soils (page 32)			
1401	Deep peat	38.10	24 382	7.89
1402	Medium peat on clay	1.00	640	.21
1402.2	Medium peat on sand	.44	284	.09
1403	Shallow peat on clay	.58	371	.12
1410	Peaty loam	2.35	1 504	.49
1450	Black mixed loam	19.72	12 622	4.09
1454	Mixed loam (bottom land)	8.51	5 446	1.76
1482	Beach sand (mixed sand and peat)	7.79	4 988	1.61
	(e) Miscellaneous (page 38)			
	Lakes	17.99	11 512	3.72
	Total	482.82	309 003	100.00

The soils of Lake county are divided into the following classes:

(1) Upland prairie soils, usually rich in organic matter. These were covered originally with prairie grasses, the partially decayed roots of which have been the source of the organic matter. The flat, poorly drained areas contain the highest amounts of organic matter, owing to the more luxuriant growth of grasses there and the better chance for their preservation by the excessive moisture in the soil.

(2) Upland timber soils, including nearly all upland areas that were formerly covered with forests. These soils contain much less organic matter than the soils of the prairies because the large roots of dead trees and the surface accumulations of leaves, twigs, and fallen trees were burned by forest fires, or suffered almost complete decay, instead of being incorporated with the soil.

(3) Terrace soils, which include bench lands, or second bottom lands, that were formed at the time of the melting of the glacier, when the valleys were flooded and the streams overloaded with coarse sediment. Deposits of gravel were formed which later have been cut thru in part by the streams during their ordinary stages. These benches form soil types that are usually underlain by gravel or sand.

(4) Swamp and bottom-land soils, which include the overflow lands or flood plains along the streams, the swamps around some of the lakes, the poorly drained lowlands, and the area of sand beaches deposited by Lake Chicago.

Table 1 shows the area of each type of soil in Lake county in square miles and in acres, and its percentage of the total area. It will be noted that the yellow-gray silt loam, or undulating timber land, occupies the larger part of the county. The accompanying map shows the location and boundary lines of every type of soil in the county, even down to areas of a few acres.

THE INVOICE AND INCREASE OF FERTILITY IN LAKE COUNTY SOILS

SOIL ANALYSIS

In order to avoid confusion in applying in a practical way the technical information contained in this report, the results are given in the most simplified form. The composition reported for a given soil type is, as a rule, the average of many analyses, which, like most things in nature, show more or less variation; but for all practical purposes the average is most trustworthy and sufficient. (See Bulletin 123, which reports the general soil survey of the state, together with many hundred individual analyses of soil samples representing twenty-five of the most important and most extensive soil types in the state.)

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but, as explained in the Appendix, the rate of liberation is governed by many factors. Also, as there stated, probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the

poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that the productive power of normal soil in humid sections depends upon the stock of plant food contained in the soil and upon the rate at which it is liberated.

The fact may be repeated, too, that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all plants, only one (hydrogen) from water, while seven are secured from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes) in case the amount liberated from the soil is insufficient. But even the leguminous plants (which include the clovers, peas, beans, alfalfa, and vetches), in common with other agricultural plants, secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron, and sulfur) and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

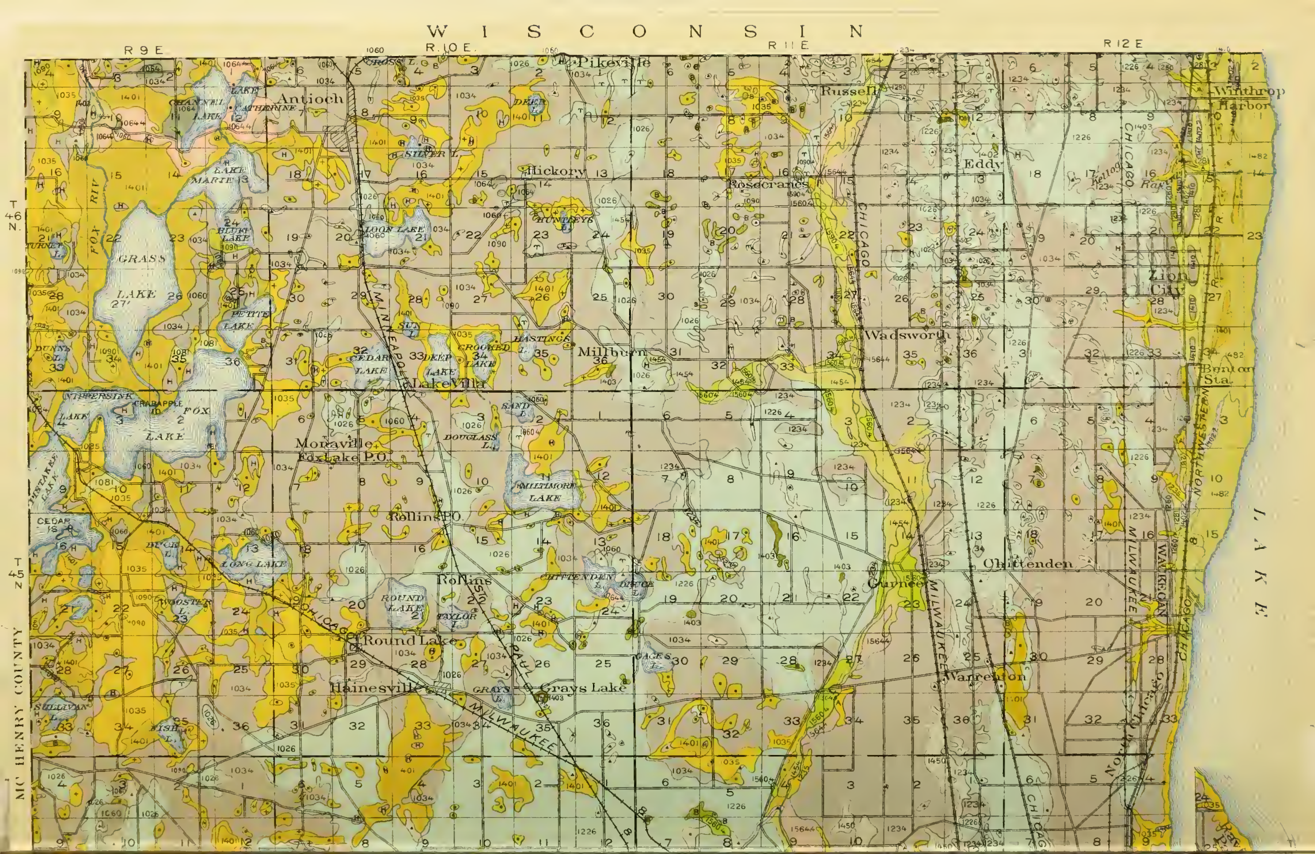
Table A in the Appendix shows the requirements of large crops for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally from natural sources in sufficient abundance, compared with the amounts needed by plants, so that they are never known to limit the yield of common farm crops.)

In Table 2 are reported the amounts of organic carbon (the best measure of the organic matter) and the total amounts of the five important elements of plant food contained in 2 million pounds of the surface soil of each type,—the plowed soil of an acre about 6⅔ inches deep. In addition, the table shows the amount of limestone present, if any, or the soil acidity as measured by the amount of limestone required to neutralize the acidity existing in the soil.

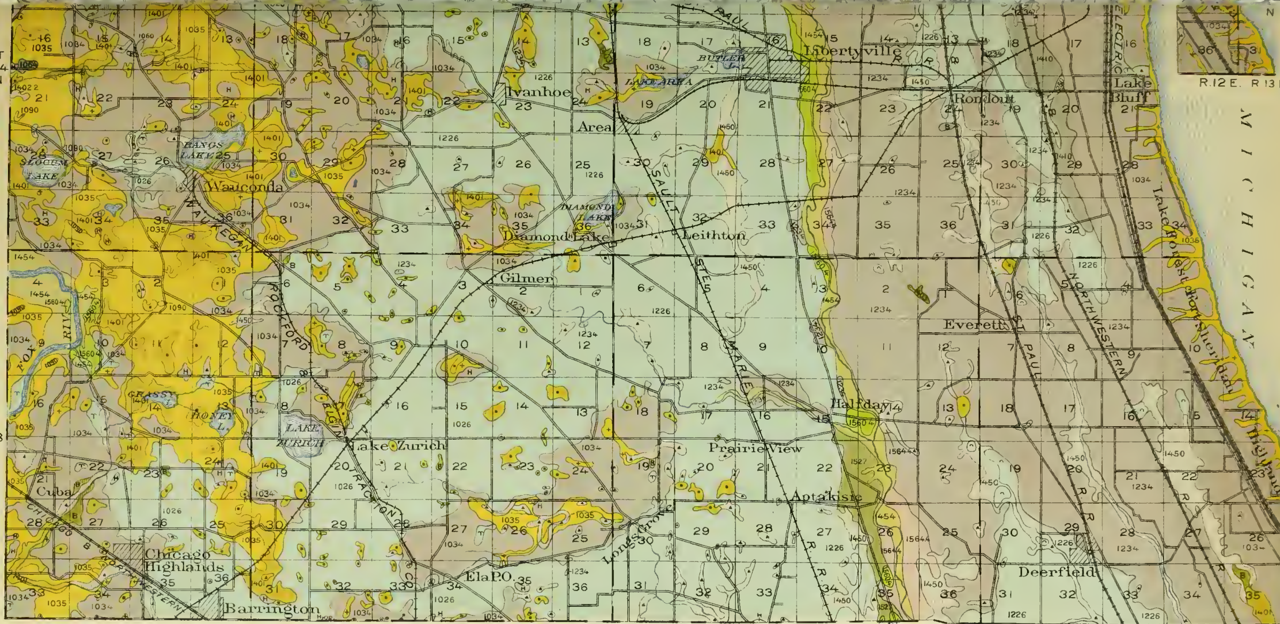
The soil to the depth indicated includes at least as much as is ordinarily turned with the plow, and represents that part with which the farm manure, limestone, phosphate, or other fertilizer applied in soil improvement is incorporated. It is the soil stratum that must be depended upon in large part to furnish the necessary plant food for the production of crops, as will be seen from the information given in the Appendix. Even a rich subsoil has little or no value if it lies beneath a worn-out surface, for the weak, shallow-rooted plants will be unable to reach the supply of plant food in the subsoil. If, however, the fertility of the surface soil is maintained at a high point, then the plants, with a vigorous start from the rich surface soil, can draw upon the subsurface and subsoil for a greater supply of plant food.

By easy computation it will be found that the most common prairie soil of Lake county does not contain more than enough total nitrogen in the plowed soil for the production of maximum crops for fifteen rotations (60 years), while the still more extensive upland timber soil (yellow-gray silt loam) contains only about one-third as much nitrogen as the prairie land, or sufficient for only eighteen 100-bushel crops of corn, grain, and stalks.

With respect to phosphorus, the condition differs only in degree, half the soil area of the county containing no more of that element than would be re-



WISCONSIN
R 9 E
R. 10 E.
R 11 E
R 12 E
LAKE
T 46 N.
T 45 N
MC HENRY COUNTY
Pikeville
Antioch
Russell
Winthrop Harbor
Eddy
Hickory
Rosecrans
Zion City
Benton Sta.
Wadsworth
Millburn
Lake Villa
Moraville
Fox Lake P.O.
Rollins P.O.
Rollins
Gurnee
Chittenden
Waukegan
Round Lake
Hainesville
Grays Lake
Warrenton
Grass Lake
Fox Lake
Channel Lake
Lake Catherine
Lake Marie
Bluff Lake
Petite Lake
Loon Lake
Cedar Lake
Deep Lake
Crooked Lake
Sun L.
Silver L.
Deer L.
Hastings L.
Sand L.
Douglass L.
Huntleys L.
Miltmore Lake
Chittenden L.
Druce L.
Round Lake
Taylor L.
Grays L.
Long Lake
Duck L.
Wooster L.
Fish L.
Sullivan L.
Pistakee Lake
Nippersink Lake
Crabapple
Cedar Is.
Turner L.
Dunns L.
Fox Riv.
Chicago
Milwaukee
Northwestern
Minneapolis
St. Paul
North Chicago
Kellogg Ravine



LEGEND

UPLAND PRAIRIE SOILS

- T 1026 / n 1226 — Brown silt loam
- 1060 / 1260 — Brown sandy loam

UPLAND TIMBER SOILS

- H 1034 / 1234 — Yellow-gray silt loam
- + 1035 / A 1235 — Yellow silt loam
- 1064 — Yellow-gray sandy loam
- 1064.4 — Yellow-gray sandy loam on gravel
- 1081 / 1281 — Dane sand
- 1090 / 1290 — Gravelly loam

TERRACE SOILS

- 1527 — Brown silt loam over gravel
- 1564.4 — Yellow-gray sandy loam on gravel
- 1560.4 — Brown sandy loam on gravel
- 1590.4 — Gravelly loam on gravel

SWAMP AND BOTTOM LAND SOILS

- • 1401 — Deep peat
- B 1402 — Medium peat on clay
- 1402.2 — Medium peat on sand
- 1403 — Shallow peat on clay
- 1410 — Peaty loam
- ▲ 1450 — Black mixed loam
- 1454 — Mixed loam (Bottom land)
- 1482 — Beach sand
- 1000 — Late Wisconsin Moraines
- 1200 — Late Wisconsin Glaciation

Scale
0 ¼ ½ 1 2 Miles

A HOEN & CO BALTIMORE

SOIL SURVEY MAP OF LAKE COUNTY

UNIVERSITY OF ILLINOIS AGRICULTURAL EXPERIMENT STATION

quired for ten crop rotations if such yields were secured as are suggested in Table A of the Appendix. It will be seen from the same table that in the case of the cereals about three-fourths of the phosphorus taken from the soil is deposited in the grain, while only one-fourth remains in the straw or stalks.

On the other hand, the potassium in the most common soil type is sufficient for 36 centuries if only the grain is sold, or for 560 years even if the total crops should be removed and nothing returned. The corresponding figures are about 2,300 and 540 years for magnesium, and about 7,800 and 200 years for calcium. Thus, when measured by the actual crop requirements for plant food, potassium is no more limited than magnesium and calcium; and as explained in the Appendix, with magnesium, and more especially with calcium, we must also consider the fact that loss by leaching is far greater than by cropping.

These general statements relating to the total quantities of plant food in the plowed soil of the most prevalent type in the county certainly emphasize the fact that the supplies of some of these necessary elements of fertility are extremely limited when measured by the needs of large crop yields for even one or two generations of people.

TABLE 2.—FERTILITY IN THE SOILS OF LAKE COUNTY, ILLINOIS

Average pounds per acre in two million pounds of surface soil (about 0 to 6⅔ inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity
	Upland Prairie Soils								
1226	Brown silt loam........	89 950	7 490	1 430	46 930	12 680	13 300		50
1060	Brown sandy loam......	8 300	640	420	25 200	2 680	5 020		40
	Upland Timber Soils								
1234	Yellow-gray silt loam...	32 220	2 720	750	46 300	9 210	7 820		40
1035	Yellow silt loam........	20 900	1 880	720	58 300	12 380	6 270		30
1064	Yellow-gray sandy loam.	18 000	1 720	800	34 280	5 480	7 220		20
1064.4	Yellow-gray sandy loam on gravel	20 660	1 520	920	34 580	5 080	10 460		40
1281	Dune sand	26 000	1 860	780	23 960	4 920	8 760	12 720	140
1090	Gravelly loam	33 580	2 760	1 000	30 920	11 960	16 000		
	Terrace Soils								
1527	Brown silt loam over gravel	62 340	5 180	1 340	36 340	7 460	8 900		60
1564.4	Yellow-gray sandy loam on gravel	30 820	2 680	1 120	38 600	7 480	9 540		40
1560.4	Brown sandy loam on gravel	28 280	2 420	780	37 660	7 680	10 680		20
1590.4	Gravelly loam on gravel	37 380	3 240	1 420	33 380	8 960	9 160	1 020	
	Swamp and Bottom-Land Soils								
1401	Deep peat (slightly decomposed moss)	445 080	7 990	670	6 120	3 360	2 850		8 380
1401	Deep peat, normal phase	398 040	32 570	1 540	3 900	6 260	24 970		140
1402	Medium peat on clay...	206 230	17 380	1 240	16 450	9 140	18 450		50
1402.2	Medium peat on sand...	271 560	18 450	1 080	12 420	8 080	18 860		80
1403	Shallow peat on clay...	380 800	27 420	1 110	6 410	6 310	28 780		290
1410	Peaty loam	334 170	31 650	2 300	18 540	13 410	40 050	Often	
1450	Black mixed loam......	164 480	13 640	1 740	35 000	14 140	24 760	16 080	
1454	Mixed loam (bottom land)	89 440	8 190	1 490	34 690	45 460	91 180	301 130	
1482	Beach sand	5 420	420	660	16 100	9 620	14 320		20

The variation among the different types of soil in Lake county with respect to their content of important plant-food elements is also very marked. Thus the yellow silt loam contains in 2 million pounds of surface soil sufficient total nitrogen for 12 "maximum" crops of corn, sufficient phosphorus for 31 crops, and potassium for 800 such crops; while the deep peat contains in 1 million pounds of surface soil, nitrogen for 217, phosphorus for 67, and potassium for only 53 corn crops of 100 bushels each. Each of these soil types covers about 8 percent of the county. More than 90 percent of the soils of the county contain no limestone in the surface or subsurface to a depth of 20 inches, altho the presence of limestone is beneficial for most crops, especially for the valuable biennial and perennial legumes, such as the clovers and alfalfa.

With an inexhaustible supply of nitrogen in the air, and with 46,000 pounds of potassium in the most common timber soil, the economic loss in farming such land with some acidity and with only 750 pounds of total phosphorus in the plowed soil can be appreciated only by the man who fully realizes that in less than one generation the crop yields could be doubled by the proper use of limestone and phosphorus in rational farm systems, without change of seed or season and with very little more work than is now devoted to the fields. Fortunately, some definite field experiments have already been conducted on this most extensive type of soil in Lake county.

RESULTS OF EXPERIMENTS ON ANTIOCH FIELD

Table 3 shows in detail thirteen years' results secured from the Antioch soil experiment field located on the farm of Mr. D. M. White, on the yellow-gray silt loam of the late Wisconsin glaciation. Table 4 is a financial summary of these results.

The Antioch field was started in order to learn as quickly as possible what effect would be produced by the addition to this type of soil, of nitrogen, phosphorus, and potassium, singly and in combination. These elements were all added in commercial form until 1911, after which the use of commercial nitrogen was discontinued and crop residues were substituted in its place. (See report of Urbana field for further explanations, page 9.) Only a small amount of lime was applied at the beginning, in harmony with the teaching which was common at that time; furthermore, Plot 101 proved to be abnormal, so that no conclusions can be drawn regarding the effect of lime. In order to ascertain the effect produced by additions of the different elements singly, Plot 102 must be regarded as the check plot. Three other comparisons are also possible to determine the effect of each element under different conditions.

As an average of 40 tests (4 each year for ten years), liberal applications of commercial nitrogen produced a slight decrease in crop values; but as an average of thirteen years each dollar invested in phosphorus paid back $2.54 (Plot 104), while potassium applied in addition to phosphorus (Plot 108) produced no increase, the crops being valued at the lower prices used in the tabular statement. Thus, while the detailed data show great variation, owing both to some irregularity of soil and to some very abnormal seasons, with three almost complete crop failures (1904, 1907, and 1910), yet the general summary strongly confirms the analytical data in showing the need of applying phosphorus and

TABLE 3.—CROP YIELDS IN SOIL EXPERIMENTS, ANTIOCH FIELD

Plot	Yellow-gray silt loam, undulating timberland; late Wisconsin glaciation — Soil treatment applied[1]	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912	Clover 1913[2]	Wheat 1914
		Bushels or tons per acre												
101	None	44.8	36.6	17.8	18.5	35.9	12.4	65.6	12.2	5.2	34.4	21.3	.50	30.8
102	Lime	45.1	38.9	12.8	10.3	31.5	9.5	61.6	11.7	3.0	24.6	17.5	.60	30.0
103	Lime, nitrogen	46.3	40.8	2.8	17.8	37.8	6.4	60.3	13.0	1.4	10.4	24.4	([3])	40.8
104	Lime, phosphorus	50.1	53.6	12.5	35.8	57.4	13.4	70.9	23.3	6.8	37.4	49.1	1.32	54.2
105	Lime, potassium	48.2	50.2	9.7	21.7	34.9	12.9	62.5	13.5	4.6	20.4	18.8	.72	34.0
106	Lime, nitrogen, phosphorus	56.6	62.7	15.9	15.2	59.3	20.9	49.1	33.8	6.0	37.0	46.9	([3])	41.3
107	Lime, nitrogen, potassium	52.1	54.9	10.3	11.8	39.0	11.1	52.6	21.0	1.6	7.0	16.9	([3])	43.2
108	Lime, phosphorus, potassium	60.7	66.0	19.7	28.7	59.1	18.3	59.4	26.2	3.2	42.2	35.9	1.60	46.0
109	Lime, nitrogen, phosphorus, potassium	61.2	69.1	31.9	18.0	65.9	31.4	51.9	30.5	3.0	44.2	31.9	([3])	41.0
110	Nitrogen, phosphorus, potassium	59.7	71.8	37.2	16.3	66.3	28.8	55.9	34.5	4.0	49.0	38.1	([3])	37.8

Increase: Bushels or Tons per Acre

	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912	Clover 1913	Wheat 1914
For nitrogen	1.2	1.9	-10.0	7.5	6.3	-3.1	-1.3	1.3	-1.6	-14.2	6.9		10.8
For phosphorus	5.0	14.7	-.3	25.5	25.9	3.9	9.3	11.6	3.8	12.8	31.6	.72	24.2
For potassium	3.1	11.3	-3.1	11.4	3.4	3.4	.9	1.8	1.6	-4.2	1.3	.12	4.0
For nitrogen, phosphorus over phosphorus	6.5	9.1	3.4	-20.6	1.9	7.5	-21.8	10.5	-.8	-.4	2.2		-12.9
For phosphorus, nitrogen over nitrogen	10.3	21.9	13.1	-2.6	21.5	14.5	-11.2	20.8	4.6	26.6	22.5		.5
For postassium, nitrogen, phosphorus over nitrogen, phosphorus	4.6	6.4	16.0	2.8	6.6	10.5	2.8	-3.3	-3.0	7.2	-15.0		-.3

[1]Crop residues in place of commercial nitrogen after 1911.
[2]Figures in parentheses indicate bushels of seed; the others, tons of hay.
[3]No seed produced: clover plowed under on these plots.

the profit from its use, and the loss in adding potassium. In most cases commercial nitrogen damaged the small grains by causing the crop to lodge; but in those years when a corn yield of 40 bushels or more was secured by the application of phosphorus either alone or with potassium, then the addition of nitrogen produced an increase.

TABLE 4.—VALUE OF CROPS PER ACRE IN THIRTEEN YEARS, ANTIOCH FIELD

Plot	Soil treatment applied	Total value of thirteen crops	
		Lower prices[1]	Higher prices[2]
101	None	$135.12	$193.03
102	Lime	119.74	171.06
103	Lime, nitrogen	124.70	178.15
104	Lime, phosphorus	202.20	288.85
105	Lime, potassium	138.88	198.40
106	Lime, nitrogen, phosphorus	179.41	256.31
107	Lime, nitrogen, potassium	133.54	190.77
108	Nitrogen, phosphorus, potassium	201.35	287.65
109	Lime, nitrogen, phosphorus, potassium	191.22	273.18
110	Nitrogen, phosphorus, potassium	181.18	258.83

Value of Increase per Acre in Thirteen Years

For nitrogen	$ 4.96	$ 7.09
For phosphorus	82.46	117.79
For *nitrogen* and phosphorus over phosphorus	–22.79	–32.54
For *phosphorus* and nitrogen over nitrogen	54.71	78.16
For *potassium,* nitrogen, and phosphorus over nitrogen and phosphorus	11.81	16.87

[1]Wheat at 70 cents a bushel, corn at 35 cents, oats at 28 cents, hay at $7 a ton.
[2]Wheat at $1 a bushel, corn at 50 cents, oats at 40 cents, hay at $10 a ton.

PLATE 1.—CLOVER IN 1913 ON ANTIOCH FIELD
LIME APPLIED AND RESIDUES PLOWED UNDER

From a comparison of the results from the Urbana, Sibley, and Bloomington fields (see following pages), we must conclude that better yields are to be secured by providing nitrogen by means of farm manure or legume crops grown in the rotation than by the use of commercial nitrogen, which is evidently too readily available, causing too rapid growth and consequent weakness of straw; and of course the atmosphere is the most economic source of nitrogen where that element is needed for soil improvement in general farming. (See Appendix for detailed discussion of "Permanent Soil Improvement."

RESULTS OF FIELD EXPERIMENTS AT URBANA

No soil experiment field has been conducted on the brown silt loam of the late Wisconsin glaciation, but we may well consider the results from long-continued experiments on similar soil in the early Wisconsin glaciation, as at Urbana in Champaign county, at Sibley in Ford county, and at Bloomington in McLean county. (Long-cultivated fields of brown silt loam in the late Wisconsin glaciation are sometimes found to contain no more phosphorus or nitrogen than the average in the brown silt loam of the early Wisconsin.)

A three-year rotation of corn, oats, and clover was begun on the North Farm at the University of Illinois in 1902, on three fields of typical brown silt loam prairie land which, after twenty years or more of pasturing, had grown corn in 1895, 1896, and 1897 (when careful records were kept of the yields produced), and had then been cropped with clover and grass on one field (Series 100), oats on another (Series 200), and oats, cowpeas, and corn on the third field (Series 300) until 1901.

PLATE 2.—CLOVER IN 1913 ON ANTIOCH FIELD
LIME AND PHOSPHORUS APPLIED

From 1902 to 1910 the three-year rotation (with cowpeas in place of clover in 1902) was followed; the average yields are recorded in Table 5. A small crop of cowpeas in 1902 and a partial crop of clover in 1904 constituted all the hay harvested during the first rotation, mammoth clover grown in 1903 having lodged so that it was plowed under. (The yields were taken by carefully weighing the clover from small representative areas, but while the differences were thus ascertained and properly credited temporarily to the different soil treatments, they must ultimately reappear in subsequent crop yields, and consequently the 1903 clover crop is omitted from Table 5 in computing yields and values.) The average yields given represent one-third of the two small crops.

From 1902 to 1907 legume cover crops (Lc), such as cowpeas and clover, were seeded in the corn at the last cultivation on Plots 2, 4, 6, and 8, but the growth was small and the effect, if any, was to decrease the returns from the regular crops. Since 1907 crop residues (R) have been returned to those plots. These consist of the stalks of corn, the straw of small grains, and all legumes except alfalfa hay and the seed of clover and soybeans.

On Plots 3, 5, 7, and 9, manure (M) was applied for corn at the rate of 6 tons per acre during the second rotation, and subsequently as many tons of manure have been applied as there were tons of air-dry produce harvested from the corresponding plots.

Lime (L) was applied on Plots 4 to 10 at the rate per acre of 250 pounds of air-slaked lime in 1902 and 600 pounds of limestone in 1903. Subsequently 2 tons per acre of limestone was applied to these plots on Series 100 in 1911, on Series 200 in 1912, on Series 300 in 1913, and on Series 400 in 1914; also 2½ tons per acre on Series 500 in 1911, two more fields having been brought into rotation, as explained below.

Phosphorus (P) has been applied on Plots 6 to 9 at the rate of 25 pounds per acre per annum in 200 pounds of steamed bone meal; but beginning with 1908, one half of each phosphorus plot has received 600 pounds of rock phosphate in place of the 200 pounds of bone meal, the usual practice being to apply and plow under at one time all phosphorus and potassium required for the rotation.

Potassium (K=kalium) has been applied on Plots 8 and 9 at the yearly rate of 42 pounds per acre in 100 pounds of potassium sulfate, regularly in connection with the bone meal and rock phosphate.

On Plot 10 about five times as much manure and phosphorus are applied as on the other plots, but this ''extra heavy'' treatment was not begun until 1906, only the usual lime, phosphorus, and potassium having been applied in previous years. The purpose in making these heavy applications is to try to determine the climatic possibilities in crop yields by removing the limitations of inadequate fertility.

Series 400 and 500 were cropped in corn and oats from 1902 to 1910, but the corresponding plots were treated the same as in the three-year rotation. Beginning with 1911, the five series have been used for a combination rotation, wheat, corn, oats, and clover being rotated for five years on four fields, while alfalfa occupies the fifth field, which is then to be brought under the four-crop system to make place for alfalfa on one of the other fields for another five-year period, and so on. (See Table 6.)

TABLE 5.—YIELDS PER ACRE, THREE-YEAR AVERAGES: URBANA FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Serial plot No.	First rotation, 1902-1904						Second rotation, 1905-1907						Third rotation, 1908-1910					
	Soil treatment	Coru, bu.	Oats, bu.	Hay, tons	Value of 3 crops		Soil treatment	Corn, bu.	Oats, bu.	Clover, tons	Value of 3 crops		Soil treatment	Corn, bu.	Oats, bu.	Clover, tons (bu.)	Value of 3 crops	
					Lower prices	Higher prices					Lower prices	Higher prices					Lower prices	Higher prices
1	0........	75.4	48.8	.49	$43.48	$62.12	0......	71.5	46.6	2.07	$52.56	$75.09	0......	49.4	40.8	2.30	$44.81	$64.02
2	Le......	77.4	45.1	.44	42.80	61.14	Le.....	68.5	52.0	1.83	51.34	73.35	R......	51.5	43.4	(1.93)	43.69	62.41
3	0........	75.3	50.4	.41	43.33	61.91	M.....	80.5	54.8	2.19	58.84	84.07	M.....	69.3	46.2	2.53	54.90	78.43
4	LeL.....	78.4	47.3	.42	43.62	62.32	LeL...	72.3	58.6	1.98	55.57	79.39	RL....	58.1	45.7	(2.02)	47.27	67.53
5	L.......	80.8	58.2	.44	47.66	68.08	ML....	84.8	59.8	2.46	63.64	90.92	ML....	74.9	47.5	2.94	60.09	85.85
6	LeLP....	88.0	52.5	.50	49.00	70.00	LeLP..	90.4	70.7	2.69	70.26	100.38	RLP...	83.8	54.5	(2.64)	63.07	90.10
7	LP......	88.8	56.6	.98	53.79	76.84	MLP...	93.2	71.6	3.47	76.96	109.94	MLP...	86.6	55.4	4.17	75.01	107.16
8	LeLPK..	90.1	48.3	.64	49.53	70.77	LeLPK	93.8	71.7	3.06	74.32	106.18	RLPK	86.7	53.5	(1.99)	59.26	84.65
9	LPK....	90.5	54.3	1.34	56.26	80.37	MLPK	95.6	66.9	3.73	78.30	111.86	MLPK	90.9	53.6	3.90	74.12	105.89
10	LPK....	86.5	53.2	1.23	53.78	76.83	MxLPx	90.1	62.9	2.86	69.17	98.81	MxLPx	81.3	54.3	3.79	70.19	100.27

Le=legume cover crop; L=lime; P=phosphorus; K=potassium; M=manure; x=extra heavy applications of manure and phosphorus; R=crop residues (corn stalks, straw of wheat and oats, and all legumes except seed).

TABLE 6.—YIELDS PER ACRE, FOUR-YEAR AVERAGES, 1911-1914: URBANA FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Serial plot No.	Soil treatment	Wheat, bu.	Corn, bu.	Oats, bu.	Soybeans–3, tons (bu.)	Clover–1, tons (bu.)	Alfalfa, tons	Value of 5 crops	
								Lower prices	Higher prices
1	0.......	18.3	50.8	39.8	1.60	1.70	1.70	$65.00	$92.87
2	R.......	19.7	53.8	40.6	(20.1)	(.74)	1.27	64.72	92.47
3	M.......	20.3	59.3	48.8	1.60	1.43	1.13	67.44	96.35
4	RL......	22.3	55.7	42.8	(19.0)	(1.03)	1.19	67.20	96.00
5	ML.....	24.9	58.6	51.6	1.66	1.94	1.67	76.19	108.84
6	RLP....	37.4	62.2	58.7	(21.0)	(2.48)	2.69	98.58	140.83
7	MLP....	36.6	63.8	60.9	1.88	2.90	2.63	98.36	140.51
8	RLPK...	36.1	58.9	59.1	(22.2)	(1.41)	2.58	94.61	135.16
9	MLPK..	35.3	59.6	65.1	2.09	2.72	2.66	98.15	140.22
10	MxLPx..	43.5	55.7	67.2	2.14	2.94	2.84	105.02	150.03

From 1911 to 1914 soybeans were substituted three years because of clover failure, and three-fourths of the soybeans and one-fourth of the clover are used to compute values. Alfalfa from the 1911 seeding so nearly failed that after cutting one crop in 1912, the field was plowed and reseeded. The average yield reported for alfalfa in Table 6 is one-fourth of the combined crops of 1912, 1913, and 1914.

PLATE 3.—CLOVER IN 1913 ON URBANA FIELD
FARM MANURE APPLIED
YIELD, 1.43 TONS PER ACRE

The "higher prices" allowed for produce are $1 a bushel for wheat and soybeans, 50 cents for corn, 40 cents for oats, $10 for clover seed, and $10 a ton for hay; while the "lower prices" are 70 percent of these values, or 70 cents for wheat and soybeans, 35 cents for corn, 28 cents for oats, $7 for clover seed, and $7 a ton for hay. The double set of values is used to emphasize the fact that a given practice may or may not be profitable, depending upon the prices of farm produce. The lower prices are conservative, and unless otherwise stated, they are the values regularly used in the discussion of results. It should be understood that the increase produced by manures and fertilizers requires increased expense for binding twine, shocking, stacking, baling, threshing, hauling, storing, and marketing. Measured by the average Illinois prices for the past ten years, these lower values are high enough for farm crops standing in the field ready for the harvest.

The cost of limestone delivered at the farmers' railroad station in carload lots averages about $1.25 per ton. Steamed bone meal in carloads costs from $25 to $30 per ton. Fine-ground raw rock phosphate containing from 260 to 280 pounds of phosphorus, or as much as the bone meal contains, ton for ton, but in less readily available form, usually costs the farmer from $6.50 to $7.50 per ton in carloads. (Acid phosphate carrying half as much phosphorus, but in soluble form, commonly costs from $15 to $17 per ton delivered in carload lots

PLATE 4.—CLOVER IN 1913 ON URBANA FIELD
FARM MANURE, LIMESTONE, AND PHOSPHORUS APPLIED
YIELD, 2.90 TONS PER ACRE

in central Illinois.) Under normal conditions potassium costs about 6 cents a pound, or $2.50 per acre per annum for the amount applied in these experiments, the same as the cost of 200 pounds of steamed bone meal at $25 per ton.

To these cash investments must be added the expense of hauling and spreading the materials. This will vary with the distance from the farm to the railroad station, with the character of roads, and with the farm force and the immediate requirements of other lines of farm work. It is the part of wisdom to order such materials in advance to be shipped when specified, so that they may be received and applied when other farm work is not too pressing and, if possible, when the roads are likely to be in good condition.

The practice of seeding legume cover crops in the cornfield at the last cultivation where oats are to follow the next year has not been found profitable, as a rule, on good corn-belt soil; but the returning of the crop residues to the land may maintain the nitrogen and organic matter equally as well as the hauling and spreading of farm manure,—and this makes possible permanent systems of farming on grain farms as well as on live-stock farms, provided, of course, that other essentials are supplied. (Clover with oats or wheat, as a cover crop to be plowed under for corn, often gives good results.)

At the lower prices for produce, manure (6 tons per acre) was worth $1.05 a ton as an average for the first three years it was applied (1905 to 1907). The next rotation the average application of 10.21 tons per acre on Plot 3 was worth $10.09, or 99 cents a ton. The last four years, 1911 to 1914, the average amount applied (once for the rotation) on Plot 3 was 11.35 tons per acre, worth $6.42, or 57 cents a ton, as measured by its effect on the wheat, corn, oats, soybeans, and clover. Thus, as an average of the ten years' results, the farm manure applied to Plot 3 has been worth 84 cents a ton on common corn-belt prairie soil, with a good crop rotation including legumes. During the last rotation period moisture has been the limiting factor to such an extent as probably to lessen the effect of the manure.

Aside from the crop residues and manure, each addition affords a duplicate test as to its effect. Thus the effect of limestone is ascertained by comparing Plots 4 and 5, not with Plot 1, but with Plots 2 and 3; and the effect of phosphorus is ascertained by comparing Plots 6 and 7 with Plots 4 and 5, respectively.

As a general average the plots receiving limestone have produced $1.22 an acre a year more than those without limestone, and this corresponds to more than $6 a ton for all of the limestone applied; but the amounts used before 1911 were so small and the results vary so greatly with the different plots, crops, and seasons that final conclusions cannot be drawn until further data are secured, the first 2-ton applications having been completed only for 1914. However, all comparisons by rotation periods show some increase for limestone, varying from 82 cents on three acres (Plot 4) during the first rotation, to $8.75 on five acres (Plot 5) as an average of the last four years; and the need of limestone for best results and highest profits seems well established.

As an average of duplicate trials (Plots 6 and 7), phosphorus in bone meal produced increases valued at $1.92 per acre per annum for the first three years and at $4.67 for the next three; and the corresponding subsequent average increases from bone meal and raw phosphate (one-half plot of each) were $5.12 for the third rotation and $5.36 for the last four years, 1911 to 1914. The annual

expense per acre for phosphorus is $2.80 in bone meal at $28 a ton, or $2.10 for rock phosphate at $7 a ton.

Potassium, applied at an estimated cost of $2.50 an acre a year, seemed to produce slight increases, as an average, during the first and second rotations; but subsequently those increases have been slightly more than lost in reduced average yields, the net result to date being an average loss of $2.53 per acre per annum, including the cost of the potassium.

Thus phosphorus nearly paid its cost during the first rotation, and has subsequently paid its annual cost and about 100 percent net profit; while potassium, as a general average, has produced no effect, and money spent for its application has been lost. These field results are in harmony with what might well be expected on land naturally containing in the plowed soil of an acre only about 1,200 pounds of phosphorus and more than 36,000 pounds of potassium.

The total value of five average crops harvested from the untreated land during the last four years is $65. Where limestone and phosphorus have been used together with organic manures (either crop residues or farm manure), the corresponding value exceeds $98. Thus 200 acres of the properly treated land would produce as much in crops and in value as 300 acres of the untreated land.

The excessive applications on Plot 10 have usually produced rank growth of straw and stalk with the result that oats have often lodged badly and corn has frequently suffered from drouth and eared poorly. Wheat, however, has as an average yielded best on this plot. The largest yield of corn on Plot 10 was 118 bushels per acre in 1907.

RESULTS OF EXPERIMENTS OF SIBLEY FIELD

Table 7 gives the results obtained during twelve years from the Sibley soil experiment field located in Ford county on the typical brown silt loam prairie of the Illinois corn belt.

Previous to 1902 this land had been cropped with corn and oats for many years under a system of tenant farming, and the soil had become somewhat deficient in active organic matter. While phosphorus was the limiting element of plant food, the supply of nitrogen becoming available annually was but little in excess of the phosphorus, as is well shown by the corn yields for 1903, when the addition of phosphorus produced an increase of 8 bushels, nitrogen produced no increase, but nitrogen and phosphorus together increased the yield by 15 bushels.

After six years of additional cropping, however, nitrogen appeared to become the most limiting element, the increase in the corn in 1907 being 9 bushels from nitrogen and only 5 bushels from phosphorus, while both together produced an increase of 33 bushels. By comparing the corn yields for the four years 1902, 1903, 1906, and 1907, it will be seen that the untreated land apparently grew less productive, whereas, on land receiving both phosphorus and nitrogen, the yield appreciably increased, so that in 1907, when the untreated rotated land produced only 34 bushels of corn per acre, a yield of 72 bushels (more than twice as much) was produced where lime, nitrogen, and phosphorus had been applied, altho the two plots produced exactly the same yield (57.3 bushels) in 1902.

Even in the unfavorable season of 1910 the yield of the highest producing plot exceeded the yield of the same plot in 1902, while the untreated land produced less than half as much as it produced in 1902. The prolonged drouth of 1911 resulted in almost a failure of the corn crop, but nevertheless the effect of soil treatment was seen. Phosphorus appeared to be the first limiting element again in 1909, 1910, and 1911; while the lodging of oats, especially on the nitrogen plots, in the exceptionally favorable season of 1912, produced very irregular results. In 1913, wheat averaged 6.6 bushels without nitrogen or phosphorus

TABLE 7.—CROP YIELDS IN SOIL EXPERIMENTS, SIBLEY FIELD

Brown silt loam prairie; early Wisconsin glaciation		Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912	Wheat 1913
Plot	Soil treatment applied	Bushels per acre											
101	None	57.3	50.4	74.4	29.5	36.7	33.9	25.9	25.3	26.6	20.7	84.4	5.5
102	Lime	60.0	54.0	74.7	31.7	39.2	38.9	24.7	28.8	34.0	22.2	85.6	6.8
103	Lime, nitro.	60.0	54.3	77.5	32.8	41.7	48.1	36.3	19.0	29.0	22.4	25.3	18.3
104	Lime, phos.	61.3	62.3	92.5	36.3	44.8	43.5	25.6	32.2	52.0	31.6	92.3	10.7
105	Lime, potas.	56.0	49.9	74.4	30.2	37.5	34.9	22.2	23.2	34.2	21.6	83.1	7.5
106	Lime, nitro., phos.	57.3	69.1	88.4	45.2	68.5	72.3	45.6	33.3	55.6	35.3	42.2	24.7
107	Lime, nitro., potas.	53.3	51.4	75.9	37.7	39.7	51.1	42.2	25.8	46.2	20.1	55.6	19.2
108	Lime, phos., potas.	58.7	60.9	80.0	39.8	41.5	39.8	27.2	28.5	43.0	31.8	79.7	11.8
109	Lime, nitro., phos., potas.	58.7	65.9	82.5	48.0	69.5	80.1	52.8	35.0	58.0	35.7	57.2	24.5
110	Nitro., phos., potas.	60.0	60.1	85.0	48.5	63.3	72.3	44.1	30.8	64.4	31.5	54.1	18.0
Increase: Bushels per Acre													
For nitrogen		.0	.3	2.8	1.1	2.5	9.2	11.6	−9.8	−5.0	.2	−60.3	11.5
For phosphorus		1.3	8.3	17.8	4.6	5.6	4.6	.9	3.4	18.0	9.4	6.7	3.9
For potassium		−4.0	−4.1	−.3	−1.5	−1.7	−4.0	−2.5	−5.6	.2	−.6	−2.5	.7
For nitro., phos. over phos.		−4.0	6.8	−4.1	8.9	23.7	28.8	20.0	1.1	3.6	3.7	−50.1	14.0
For phos., nitro. over nitro		−2.7	14.8	10.9	12.4	24.8	24.2	9.3	14.3	26.6	12.9	16.9	6.4
For potas., nitro., phos. over nitro., phos.		1.4	−3.2	−5.9	2.8	1.0	7.8	7.2	1.7	2.4	.4	15.0	−.2

Value of Crops per Acre in Twelve Years

Plot	Soil treatment applied	Total value of twelve crops: Lower prices	Total value of twelve crops: Higher prices
101	None	$172.89	$246.98
102	Lime	186.51	266.45
103	Lime, nitrogen	177.44	253.49
104	Lime, phosphorus	217.78	311.11
105	Lime, potassium	167.32	239.03
106	Lime, nitrogen, phosphorus	246.91	352.73
107	Lime, nitrogen, potassium	198.16	283.08
108	Lime, phosphorus, potassium	204.90	292.71
109	Lime, nitrogen, phosphorus, potassium	257.91	368.45
110	Nitrogen, phosphorus, potassium	242.47	346.38

Value of Increase per Acre in Twelve Years

For nitrogen	$ 9.07	$12.96
For phosphorus	31.27	44.66
For *nitrogen* and phosphorus over phosphorus	29.13	41.62
For *phosphorus* and nitrogen over nitrogen	69.47	99.24
For *potassium,* nitrogen, and phosphorus over nitrogen and phosphorus	11.00	15.72

(Plots 101, 102, 105) and 22.4 bushels where both nitrogen and phosphorus were added (Plots 106, 109, 110).

In the lower part of Table 7 are shown the total values per acre of the twelve crops from each of the ten different plots, the amounts varying from $167.32 to $257.91, with corn valued at 35 cents a bushel, oats at 28 cents, and wheat at 70 cents. Phosphorus without nitrogen has produced $31.27 in addition to the increase by lime, but with nitrogen it has produced $69.47 above the crop values where only lime and nitrogen have been used. The results show that in 26 cases out of 48 the addition of potassium has decreased the crop yields. Even when applied in addition to phosphorus, and with no effort to liberate potassium from the soil by adding organic matter, potassium has produced no increase in crop values as an average of the results from Plots 108 and 109.

By comparing Plots 101 and 102, and also 109 and 110, it is seen that lime has produced an average increase of $14.53, or $1.21 an acre a year. This increase on these plots is practically the same as at Urbana, and it suggests that the time is here when limestone must be applied to some of these brown silt loam soils.

While nitrogen, on the whole, has produced an appreciable increase, especially on those plots to which phosphorus has also been added, it has cost, in commercial form, so much above the value of the increase produced that the only conclusion to be drawn, if we are to utilize this fact to advantage, is that the nitrogen must be secured from the air.

RESULTS OF EXPERIMENTS ON BLOOMINGTON FIELD

Space is taken to insert Tables 8 and 9, giving all results thus far obtained from the Bloomington soil experiment field, which is also located on the brown silt loam prairie soil of the Illinois corn belt.

The general results of the thirteen years' work on the Bloomington field tell much the same story as those from the Sibley field. The rotations have differed since 1905 by the use of clover and the discontinuing of the use of commercial nitrogen on the Bloomington field,—in consequence of which phosphorus without commercial nitrogen, on the Bloomington field, has produced an even larger increase ($99.85) than has been produced by phosphorus and nitrogen over nitrogen on the Sibley field ($69.47).

It should be stated that a draw runs near Plot 110 on the Bloomington field, that the crops on that plot are sometimes damaged by overflow or imperfect drainage, and that Plot 101, occupies the lowest ground on the opposite side of the field. In part because of these irregularities and in part because only one small application has been made, no conclusions can be drawn in regard to lime. Otherwise all results reported in Table 8 are considered reliable. They not only furnish much information in themselves, but they also offer instructive comparison with the Sibley field.

Wherever nitrogen has been provided, either by direct application or by the use of legume crops, the addition of the element phosphorus has produced very marked increases, the average yearly increase for the Bloomington field being worth $7.02 an acre. This is $4.52 above the cost of the phosphorus in 200 pounds of steamed bone meal, the form in which it is applied on the Sibley and the Bloomington fields. On the other hand, the use of phosphorus without nitrogen

TABLE 8.—CROP YIELDS IN SOIL EXPERIMENTS, BLOOMINGTON FIELD

Plot	Brown silt loam prairie; early Wisconsin glaciation / Soil treatment applied	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Corn 1908	Oats 1909	Clover[2] 1910	Wheat 1911	Corn 1912	Corn 1913	Oats 1914
		Bushels or tons per acre												
101	None	30.8	63.9	54.8	30.8	.39	60.8	40.3	46.4	1.56	22.5	55.2	32.4	29.8
102	Lime	37.0	60.3	60.8	28.8	.58	63.1	35.3	53.6	1.09	22.5	47.9	30.0	40.6
103	Lime, crop residues[1]	35.1	59.5	69.8	30.5	.46	64.3	36.9	49.4	(.83)	25.6	62.5	37.5	30.8
104	Lime, phosphorus	41.7	73.0	72.7	39.2	1.65	82.1	47.5	63.8	4.21	57.6	74.5	44.1	45.0
105	Lime, potassium	37.7	56.4	62.5	33.2	.51	64.1	36.2	45.3	1.26	21.7	57.8	32.1	35.8
106	Lime, residues,[1] phosphorus	43.9	77.6	85.3	50.9	([3])	78.9	45.8	72.5	(1.67)	60.2	86.1	50.4	62.3
107	Lime, residues,[1] potassium	40.4	58.9	66.4	29.5	.81	64.3	31.0	51.1	(.33)	27.3	58.9	34.5	34.5
108	Lime, phosphorus, potassium	50.1	74.8	70.3	37.8	2.36	81.4	57.2	59.5	3.27	54.0	79.2	49.4	63.1
109	Lime, residues,[1] phosphorus, potassium	52.7	80.9	90.5	51.9	([3])	88.4	58.1	64.2	(.42)	60.4	83.4	49.0	54.4
110	Residues, phosphorus, potassium	52.3	73.1	71.4	51.1	([3])	78.0	51.4	55.3	(.60)	61.0	78.3	33.8	44.8
	Increase: Bushels or Tons per Acre													
	For residues	–1.9	–.8	9.0	1.7	–.12	1.2	1.6	–4.2		3.1	14.6	7.5	–9.8
	For phosphorus	4.7	12.7	11.9	10.4	1.07	19.0	12.2	10.2	3.12	35.1	26.6	14.1	4.4
	For potassium	.7	–3.9	1.7	4.4	–.07	1.0	.9	–8.3	.15	–.8	9.9	2.1	–4.8
	For residues, phosphorus over phosphorus	2.2	4.6	12.6	11.7	–1.65	–3.2	–1.7	8.7		2.6	11.6	6.3	17.3
	For phosphorus, residues over residues	8.8	18.1	15.5	20.4	–.46	14.6	8.9	23.1	(.84)	34.6	23.6	12.9	31.5
	For potassium, residues, phosphorus, over res., phos.	8.8	3.3	5.2	1.0	.00	9.5	12.3	–8.3	(–1.25)	.2	–2.7	–1.4	–7.9

[1]Commercial nitrogen was used 1902-1905.
[2]The figures in parenthses mean bushels of seed; the others, tons of hay.
[3]Clover smothered by previous wheat crop.

TABLE 9.—VALUE OF CROPS PER ACRE IN THIRTEEN YEARS, BLOOMINGTON FIELD

Plot	Soil treatment applied	Total value of thirteen crops	
		Lower prices	Higher prices
101	None	$186.83	$266.90
102	Lime	186.76	266.80
103	Lime, residues	193.83	276.90
104	Lime, phosphorus	286.61	409.45
105	Lime, potassium	190.53	272.19
106	Lime, residues, phosphorus	285.03	407.19
107	Lime, residues, potassium	191.10	273.00
108	Lime, phosphorus, potassium	294.91	421.31
109	Lime, residues, phosphorus, potassium	284.47	406.39
110	Residues, phosphorus, potassium	259.10	370.15
	Value of Increase per Acre in Thirteen Years		
	For residues	$ 7.07	$ 10.10
	For phosphorus	99.85	142.65
	For *residues* and phosphorus over phosphorus	−1.58	−2.26
	For *phosphorus* and residues over residues	91.20	130.29
	For *potassium,* residues, and phosphorus over residues and phosphorus	−.56	−.80

will not maintain the fertility of the soil (see Plots 104 and 106, Sibley field). As the only practical and profitable method of supplying nitrogen, a liberal use of clover or other legumes is suggested, the legume to be plowed under either directly or as manure, preferably in connection with the phosphorus applied, especially if raw rock phosphate is used.

From the soil of the best treated plots on the Bloomington field, 180 pounds per acre of phosphorus, as an average, has been removed in the thirteen crops. This is equal to 15 percent of the total phosphorus contained in the surface soil of an acre of the untreated land. In other words, if such crops could be grown

PLATE 5.—CORN IN 1912 ON BLOOMINGTON FIELD
ON LEFT, RESIDUES, LIME, AND POTASSIUM: YIELD, 58.9 BUSHELS
ON RIGHT, RESIDUES, LIME, AND PHOSPHORUS: YIELD, 86.1 BUSHELS

for eighty years, they would require as much phosphorus as the total supply in the ordinary plowed soil. The results plainly show, however, that without the addition of phosphorus such crops cannot be grown year after year. Where no phosphorus has been applied, the crops have removed only 120 pounds of phosphorus in the thirteen years, which is equivalent to only 10 percent of the total amount (1,200 pounds) present in the surface soil at the beginning of the experiment in 1902. The total phosphorus applied from 1902 to 1914, as an average of all plots where it has been used, has amounted to 325 pounds per acre and has cost $32.50. This has paid back $97.20, or 300 percent on the investment; whereas potassium, used in the same number of tests and at the same cost, has paid back only $2.20 per acre in the thirteen years, or less than 7 percent of its cost. Are not these results to be expected from the composition of such soil and the requirements of crops? (See Table 2, page 5, and also Table A in the Appendix.)

Nitrogen was applied to this field, in commercial form only, from 1902 to 1905; but clover was grown in 1906 and 1910, and a cover crop of cowpeas after the clover in 1906. The cowpeas were plowed under on all plots, and the 1910

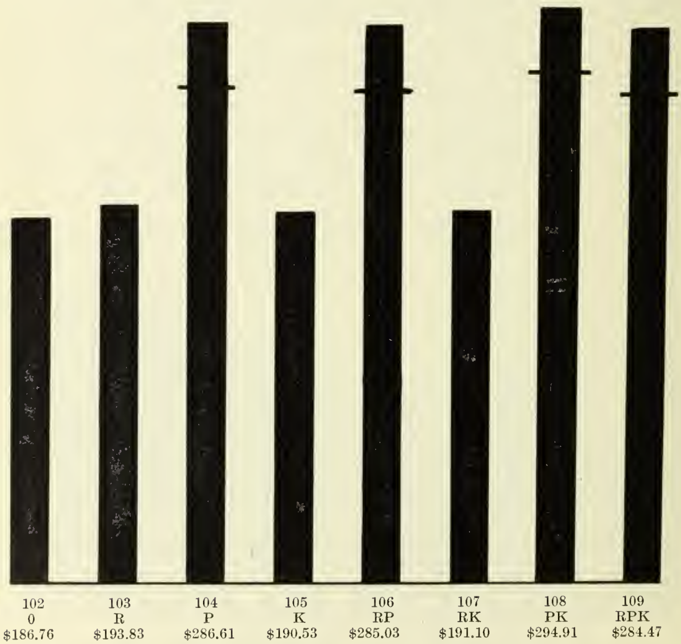


PLATE 6.—CROP VALUES FOR THIRTEEN YEARS, BLOOMINGTON EXPERIMENT FIELD
(R=residues; P=phosphorus; K=potassium, or kalium)

clover (except the seed) was plowed under on five plots (103, 106, 107, 109, and 110). Straw and corn stalks have also been returned to these plots in recent years. The effect of returning these residues to the soil has been appreciable since 1910 (an average increase on Plots 106 and 109 of 4.5 bushels of wheat, 5.4 bushels of corn, and 4.3 bushels of oats) and probably will be more marked on subsequent crops. Indeed, the large crops of corn, oats, and wheat grown on Plots 104 and 108 during the thirteen years have drawn their nitrogen very largely from the natural supply in the organic matter of the soil. The roots and stubble of clover contain no more nitrogen than the entire plant takes from the soil alone, but they decay rapidly in contact with the soil and probably hasten the decomposition of the soil humus and the consequent liberation of the soil nitrogen. But of course there is a limit to the reserve stock of humus and nitrogen remaining in the soil, and the future years will undoubtedly witness a gradually increasing difference between Plots 104 and 106, and between Plots 108 and 109, in the yields of grain crops.

Plate 6 shows graphically the relative values of the thirteen crops for the eight comparable plots, Nos. 102 to 109. The cost of the phosphorus is indicated

TABLE 10.—FERTILITY IN THE SOILS OF LAKE COUNTY, ILLINOIS

Average pounds per acre in 4 million pounds of subsurface (about 6⅔ to 20 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity
	Upland Prairie Soils								
1226	Brown silt loam........	91 050	7 940	1 960	101 020	29 810	19 310		110
1060	Brown sandy loam......	4 280	440	1 000	53 720	7 200	12 080		40
	Upland Timber Soils								
1234	Yellow-gray silt loam...	26 090	2 630	1 300	106 140	31 660	14 190		310
1035	Yellow silt loam........	23 980	2 720	1 620	136 020	40 600	13 460		60
1064	Yellow-gray sandy loam.	18 960	2 040	1 840	71 040	19 920	17 560		160
1064.4	Yellow-gray sandy loam on gravel	10 000	680	1 000	69 640	13 920	20 520		40
1281	Dune sand	18 520	720	1 160	53 840	14 280	18 040		80
1090	Gravelly loam	16 200	1 760	1 600	66 560	52 600	75 920	255 400	
	Terrace Soils								
1527	Brown silt loam over gravel................	55 560	4 760	1 680	78 440	16 920	14 880		200
1564.4	Yellow-gray sandy loam on gravel	30 320	2 400	2 080	86 880	24 880	15 160		160
1560.4	Brown sandy loam on gravel	21 080	2 200	1 200	82 440	28 160	36 240	72 520	
1590.4	Gravelly loam on gravel.	32 240	2 840	2 360	77 880	21 280	19 200	2 720	
	Swamp and Bottom-Land Soils								
1401	Deep peat (slightly decomposed moss)	988 560	32 700	1 000	3 820	7 640	18 080		1 940
1401	Deep peat	535 240	66 050	2 410	8 180	11 880	53 010		460
1402	Medium peat on clay....	295 140	24 820	2 140	33 480	18 500	38 660	3 860	
1402.2	Medium peat on sand....	388 940	25 020	1 340	15 200	15 400	35 760	8 540	
1403	Shallow peat on clay...	181 560	14 680	2 160	86 360	80 880	151 040	440 800	
1410	Peaty loam	40 620	3 760	1 300	52 460	47 720	79 200	264 300	
1450	Black mixed loam......	115 760	9 840	2 600	78 400	24 920	33 560	4 400	
1454	Mixed loam (bottom land)	117 340	10 140	3 320	72 840	94 240	191 800	Often	
1482	Beach sand	6 080	240	600	32 280	23 080	36 400	25 760	

by that part of the diagram above the short crossbars. It should be kept in mind that no value is assigned to clover plowed under except as it reappears in the increase of subsequent crops. Plots 106 and 109 are heavily handicapped because of the clover failure on those plots in 1906 and the poor yield of clover seed in 1910, whereas Plots 104 and 108 produced a fair crop in 1906 and a very large crop in 1910. Plot 106, which receives the most practical treatment for permanent agriculture (RLP), has produced a total value in thirteen years only $1.58 below that from Plot 104 (LP). (See also table on last page of cover.)

The Subsurface and Subsoil

In Tables 10 and 11 are recorded the amounts of plant food in the subsurface and the subsoil strata of the Lake county soils, but it should be remembered that these supplies are of little value unless the top soil is kept rich. Probably the most important information contained in these tables is that the subsoils are usually rich in limestone. This fact probably accounts for the moderate success with alfalfa on some Lake county farms, even where limestone has not been applied. If alfalfa is given a good start with manure or by a favorable season, until the roots reach the limestone subsoil, subsequent addition of limestone to the plowed soil may not be of much importance.

Table 11.—Fertility in the Soils of Lake County, Illinois

Average pounds per acre in 6 million pounds of subsoil (about 20 to 40 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity
	Upland Prairie Soils								
1226	Brown silt loam.....	33 940	3 350	2 480	158 810	167 400	257 290	998 570	
1060	Brown sandy loam...	6 420	660	1 500	80 580	10 800	18 120		60
	Upland Timber Soils								
1234	Yellow-gray silt loam	27 080	2 970	2 470	157 500	165 470	261 330	1 066 470	
1035	Yellow silt loam.....	22 380	14 700	2 460	178 710	198 000	263 940	1 179 780	
1064.4	Yellow-gray sandy loam on gravel....	23 100	1 680	2 340	119 880	45 060	36 000		60
1281	Dune sand	27 780	1 080	1 740	80 760	21 420	27 060		120
1090	Gravelly loam	24 300	2 640	2 400	99 840	78 900	113 880	383 100	
	Terrace Soils								
1527	Brown silt loam over gravel	29 040	2 760	2 220	124 440	42 180	34 500	32 220	
1560.4	Brown sandy loam on gravel	12 960	1 380	2 520	108 360	176 880	278 340	1 232 460	
	Swamp and Bottom-Land Soils								
1401	Deep peat (slightly decomposed moss) ..	1 443 030	48 870	1 170	6 060	9 900	30 600		2 310
1401	Deep peat	1 269 080	99 070	3 620	12 270	17 820	79 520		690
1402	Medium peat on clay.	99 180	6 840	2 760	165 780	200 640	323 040	1 258 860	
1402.2	Medium peat on sand	55 980	3 000	1 860	34 860	91 620	153 840	478 020	
1403	Shallow peat on clay.	58 560	3 360	2 280	127 260	209 400	589 860	1 980 120	
1410	Peaty loam	19 410	1 260	1 350	85 050	111 030	183 510	744 390	
1450	Black mixed loam....	43 620	3 420	1 980	122 880	57 060	74 760	183 840	
1454	Mixed loam (bottom land)............	72 480	5 730	4 380	112 470	140 400	349 710	Often	
1482	Beach sand	9 120	360	900	48 420	34 620	54 600	38 640	

INDIVIDUAL SOIL TYPES

(a) UPLAND PRAIRIE SOILS

The upland prairie soils of Lake county cover 140.38 square miles, or 29.08 percent of the entire area of the county. They are usually quite dark in color, owing to their large organic-matter content. They occupy the less rolling and comparatively level land.

Brown Silt Loam (1026 *and* 1226)

Brown silt loam is a very important and somewhat extensive type in this county, covering an area of 137.50 square miles, or 28.48 percent of the entire area of the county. It occupies much of the less rolling land, a considerable proportion of which needs artificial drainage. The presence of kettle-holes in some places makes complete drainage rather difficult; and small ponds are frequently found. Many local areas of yellow-gray silt loam, sandy loam, and peat, too small to show on the map, are also interspersed.

The surface soil, 0 to 6⅔ inches, is a brown silt loam, varying from a yellowish brown on the more rolling areas to a dark brown or black on the more nearly level and poorly drained tracts. In physical composition it varies to some extent, but normally contains from 50 to 70 percent of the different grades of silt. The clay content, as well as the organic-matter content, increases as the type approaches the black mixed loam (1450) of the swampy areas. On account of the complex character of the type, the amount of organic matter also is quite variable, ranging from 5.5 to 9.9 percent, but it averages about 7.6 percent, or 76 tons per acre. Where this type passes into the yellow-gray silt loam, the content of organic matter becomes much lower and the type much more variable. The slightly higher points, perhaps not more than a fraction of an acre in extent, may be decidedly gray or yellow, while the lower adjoining parts may be quite dark, thus giving an extremely variable phase of brown silt loam impossible to indicate on the soil map.

The subsurface is represented by a stratum varying from 6 to 15 inches in thickness. This variation is due to changing topography and the effect of erosion, the stratum becoming thinner on the more rolling areas. Less organic matter has accumulated on the more rolling areas than on the more nearly level tracts, and to a less depth. In physical composition the subsurface varies the same as the surface soil, but it normally contains a slightly larger amount of clay and a smaller amount of organic matter. The organic matter varies from 2.7 to 4.2 percent, with an average of 3.8 percent, or 38 tons per acre, or half as much as is in the surface soil. In color the subsurface varies from a dark brown or almost black to a light yellowish brown; it becomes lighter with depth, passing into the subsoil at from 12 to 22 inches.

The natural subsoil begins 12 to 22 inches beneath the surface and extends to an indefinite depth but is sampled to 40 inches. It varies from a yellow to a drabbish yellow clayey material sometimes composed of boulder clay, or drift. In some of the flat areas where material has washed in from the higher surrounding parts, the subsoil to a depth of 40 inches does not reach the boulder

clay. In many cases the stratum of gravel at 16 to 20 inches interferes with the collecting of samples.

Where properly drained, brown silt loam requires only the addition of phosphorus, limestone, and organic manures for the improvement and permanent maintenance of its productive power. As an average, phosphorus is present in the plowed soil of an acre to the extent of 1,400 pounds, compared with about 7,500 pounds of nitrogen and 47,000 pounds of potassium, altho the lighter phase, as where the type is much worn, contains as low as 1,200 pounds of phosphorus and 5,000 of nitrogen. No long-continued field experiments have been conducted by the University on this type of soil in the late Wisconsin glaciation, but the results already reported from the fields at Urbana, Sibley, and Bloomington (pages 9, 15, and 17), considered together with the composition of the soil, leave no doubt as to the wisdom of adding phosphorus to this soil and of the foolishness of spending money for potassium.

This type contains no limestone to a depth of 20 to 30 inches, and liberal use of this material should prove beneficial for clover and alfalfa, even tho the lower subsoil usually contains abundance of limestone. Farm manures, crop residues, or legume crops plowed under are needed, not only to provide nitrogen, but also to give activity to the soil for the liberation of plant food and to maintain good tilth, or good physical condition.

Brown Sandy Loam (1060 *and* 1260)

Brown sandy loam occupies only a small area in the county, amounting to 2.88 square miles, 1,844 acres, or .6 percent of the entire area.

The surface soil, 0 to 6⅔ inches, consists of a brown sandy loam varying from a light or yellowish brown to a dark brown or even black color. The areas in the western part of the country are of the lighter colored phase, while those in the eastern part, particularly north of Waukegan, partake somewhat of the nature of peaty loam and vary toward that type.

The subsurface, 6⅔ to 18 or 20 inches, consists of a brown sandy loam varying with the surface. In the western areas it is quite light in color, varying to yellow. In the eastern part of the county, it is somewhat dark, and with depth becomes somewhat gray or drab, indicating poorer drainage in many cases.

The subsoil is quite variable, in some places passing into a yellowish sand, in others into a gravelly till, while in others it becomes a drab or bluish-colored sand. This last is in the poorly drained areas.

This type of soil requires for its improvement large use of organic matter. Being loose and better aerated than the brown silt loam, it suffers greater loss of that constituent, hence greater difficulty is found in maintaining it. Crop residues, legume crops, and manure must constitute the chief materials by which the organic-matter content is maintained. In phosphorus content, this type is the poorest in the county, and it is also very deficient in limestone. While the potassium content is large (25,000 pounds per acre of plowed soil), it is in part locked up in sand grains; hence, if satisfactory yields of legumes are not secured where the soil is well drained and treated with limestone and phosphorus, the addition of kainit or potassium chlorid may well be tried.

(b) UPLAND TIMBER SOILS

The upland forest soils are deficient in organic matter owing to the fact that the vegetable material from trees accumulates upon the surface and is either burned or suffers almost complete decay. Grasses which furnish large quantities of humus-forming roots do not grow to any large extent in forests. At the same time, the organic matter that had accumulated before timber began growing on these soils is being removed thru various decomposition processes, with the result that the content has become too low for best growth.

Yellow-Gray Silt Loam (1034 *and* 1234)

Yellow-gray silt loam is the most important and extensive soil type in Lake county. It is very irregularly distributed, but occupies mostly the rolling morainal areas. This type covers 196.01 square miles, 125,447 acres, or 40.59 percent of the county. It varies greatly in topography—from the characteristic billowy, or knob-and-basin, features of the moraines to the almost level morainal and intermorainal tracts.

The surface soil, 0 to 6⅔ inches, is a gray or yellowish gray silt loam, incoherent and mealy, but not granular. The physical composition varies a great deal because of the removal by erosion in some places of the thin covering of loess, thus exposing the variable drift. Many local areas of sandy or gravelly loam are found in this type, but they are too small to be shown on the map. Likewise many small areas of dark soil such as the brown silt loam or black mixed loam are found in the slight depressions; these are also too small to be shown. The amount of organic matter contained in the surface soil of this type varies from 1.8 to 3.6 percent, with an average of 2.7, or 27 tons per acre. This wide variation is due to the relation of the type to other types, the content of organic matter increasing where it grades into brown silt loam (1026 or 1226) and decreasing where it passes into yellow silt loam (1035 or 1235). In some places erosion has reduced the content of organic matter much below the normal, so that many small areas are yellow in color.

The subsurface stratum varies from 3 to 10 inches in thickness, being thinner on the more rolling areas. In color it is gray, grayish yellow, or yellow, somewhat pulverulent, but becoming more coherent and plastic with depth. On some of the areas a stratum of gravel an inch or two in thickness is encountered at a depth of 10 to 24 inches. This is formed by the washing out of the fine material from the surface drift, as may be seen on the surface of exposed drift at the present time. It has subsequently been covered with a thin deposit of loess. The amount of organic matter is very low, amounting to only 1.1 percent, or 22 tons per acre, for a stratum 13⅓ inches in thickness.

The subsoil is a yellow to a grayish yellow boulder clay. The deeper subsoil contains large amounts of limestone and shows brisk effervescence with hydrochloric acid.

In the management of this yellow-gray silt loam, one of the most essential points is the maintenance or increase of the organic matter. This is much more necessary with this type than with the brown silt loam, because this soil is naturally much more deficient in that constituent. The organic matter supplies nitrogen, liberates mineral plant food, prevents running together, and on some of the

more rolling areas, prevents washing as well as gives better tilth to the soil under all conditions.

Another essential is the application of ground limestone, so that clover, alfalfa, and other legumes may be grown more successfully. In many cases where limestone is present in the subsoil, the legume crops will grow very well, but frequently their growth may be profitably increased by the application of 2 to 5 tons per acre of limestone. Potassium is exceedingly abundant in this type of soil, while phosphorus is markedly deficient, as is readily seen from the tabular statements, which are well supported by the results already secured from the soil experiment field conducted for many years by the University of Illinois with the helpful cooperation of Mr. D. M. White, on his farm near Antioch in Lake county. (See Tables 3 and 4, pages 7 and 8.)

Yellow Silt Loam (1035 *and* 1235)

Yellow silt loam is found chiefly in the west quarter of the county where the highest part of the Valparaiso moraine occurs. The type here is not due primarily to erosion, as in most parts of the state, but to the irregularities produced in the piling up of the morainic material. Basin-like kettle-holes are found varying from 25 feet or less to 75 and possibly 100 feet in depth. Rounded knobs are also quite characteristic of this moraine. The area of this type amounts to 38.5 square miles, 24,639 acres, or 8 percent of the county.

The surface soil, 0 to 6⅔ inches, is a yellow or yellowish gray silt loam, usually containing some sand and gravel. This stratum is usually formed from drift material, the loess, if there ever was any, having been removed by erosion. Owing to its derivation, the stratum varies a great deal in physical composition. The organic-matter content averages about 1.8 percent.

The subsurface is composed of yellow drift material, as is also the subsoil.

One of the best ways to manage this type is to keep it in permanent pasture. As a rule, it cannot be satisfactorily cropped in ordinary rotations, altho it may be used very successfully for long rotations with much pasture or meadow.

Where this soil has been long cultivated and thus exposed to surface washing, it is particularly deficient in nitrogen; indeed, on such lands the low supply of nitrogen is the factor that first limits the growth of grain crops. This fact is very strikingly illustrated by the results from two pot-culture experiments reported in Tables 12 and 13, and illustrated in Plates 7 and 8.

In one experiment, a large quantity of the typical worn hill soil was collected from two different places.[1] Each lot of soil was thoroly mixed and put in ten four-gallon jars. Ground limestone was added to all the jars except the first and last in each set, those two being retained as control or check pots. The elements nitrogen, phosphorus, and potassium were added singly and in combination, as shown in Table 12.

As an average, the nitrogen applied produced a yield about eight times as large as that secured without the addition of nitrogen. While some variations in yield are to be expected, because of differences in the individuality of seed or other uncontrolled causes, yet there is no doubting the plain lesson taught by these actual trials with growing plants.

[1]Soil for wheat pots from loess-covered unglaciated area, and that for oat pots from upper Illinois glaciation.

The question arises next, Where is the farmer to secure this much-needed nitrogen? To purchase it in commercial fertilizers would cost too much; indeed, under average conditions the cost of the nitrogen in such fertilizers is greater than the value of the increase in crop yields.

But there is no need whatever to purchase nitrogen, for the air contains an inexhaustible supply of it, which, under suitable conditions, the farmer can draw upon, not only without cost, but with profit in the getting. Clover, alfalfa, cowpeas, and soybeans are not only worth raising for their own sake, but they have the power to secure nitrogen from the atmosphere if the soil contains the essential minerals and the proper nitrogen-fixing bacteria.

In order to secure further information along this line, another experiment with pot cultures was conducted for several years with the same type of worn hill soil as that used in the former experiment. The results are reported in Table 13.

To three pots (Nos. 3, 6, and 9) nitrogen was applied in commercial form, at an expense amounting to more than the total value of the crops produced. In three other pots (Nos. 2, 11, and 12) a crop of cowpeas was grown during the late summer and fall and turned under before the wheat or oats were planted.

PLATE 7.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND
(See Table 12)

TABLE 12.—CROP YIELDS IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND
(Grams per pot)

Pot No.	Soil treatment applied	Wheat	Oats
1	None	3	5
2	Limestone	4	4
3	Limestone, nitrogen	26	45
4	Limestone, phosphorus	3	6
5	Limestone, potassium	3	5
6	Limestone, nitrogen, phosphorus	34	38
7	Limestone, nitrogen, potassium	33	46
8	Limestone, phosphorus, potassium	2	5
9	Limestone, nitrogen, phosphorus, potassium	34	38
10	None	3	5
Average yield with nitrogen		32	42
Average yield without nitrogen		3	5
Average gain for nitrogen		29	37

Pots 1 and 8 served for important comparisons. After the second cover crop of cowpeas had been turned under, the yield from Pot 2 exceeded that from Pot 3; and in the subsequent years the legume green manures produced, as an average, rather better results than the commercial nitrogen. This experiment confirms that reported in Table 12, in showing the very great need of nitrogen for the improvement of this type of soil, and it also shows that nitrogen need not be purchased but that it can be obtained from the air by growing legume crops and plowing them under as green manure. Of course the soil can be very markedly improved by feeding the legume crops to live stock and returning the resulting farm manure to the land, if legumes are grown frequently enough and if the farm manure produced is sufficiently abundant and is saved and applied with care.

As a rule, it is not advisable to try to enrich this type of soil in phosphorus, for with the erosion that is sure to occur to some extent the phosphorus supply will be renewed from the subsoil.

One of the most profitable crops to grow on this land is alfalfa. To get alfalfa well started may require the use of limestone, thoro inoculation with nitrogen-fixing bacteria, and a moderate application of farm manure. If manure is not available, it is well to apply about 500 pounds per acre of acid phosphate or steamed bone meal, mix it with the soil, by disking if possible, and then plow it under. The limestone (if needed) should be applied after plowing and should be mixed with the surface soil in the preparation of the seed bed. The special

PLATE 8.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND
(See Table 13)

TABLE 13.—CROP YIELDS IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND AND NITROGEN-FIXING GREEN MANURE CROPS

(Grams per pot)

Pot No.	Soil treatment	1903 Wheat	1904 Wheat	1905 Wheat	1906 Wheat	1907 Oats
1	None	5	4	4	4	6
2	Limestone, legume	10	17	26	19	37
11	Limestone, legume, phosphorus	14	19	20	18	27
12	Limestone, legume, phosphorus, potassium	16	20	21	19	30
3	Limestone, nitrogen	17	14	15	9	28
6	Limestone, nitrogen, phosphorus	26	20	18	18	30
9	Limestone, nitrogen, phosphorus, potassium	31	34	21	20	26
8	Limestone, phosphorus, potassium	3	3	5	3	7

purpose of this treatment is to give the alfalfa a quick start in order that it may grow rapidly and thus protect the soil from washing.

Yellow-Gray Sandy Loam (1064)

Yellow-gray sandy loam occupies only small areas in Lake county, amounting to 488 acres. It is practically all found in the western part in the most broken of the morainal ridges.

The surface soil, 0 to 6⅔ inches, is a yellow or grayish yellow sandy loam, frequently containing from 15 to 25 percent of gravel. In some small areas this gravel may be absent; its presence is due to the fact that the soil is made of a sandy till. The organic-matter content is 1.8 percent, or about 18 tons per acre.

The subsurface stratum, from 3 to 8 inches in thickness, differs from the surface in being of a lighter color, owing to the smaller amount of organic matter present, about .3 percent. At a depth of about 12 to 16 inches on much of this type, a stratum of gravelly material exists thru which it is practically impossible to bore with an auger.

The subsoil varies from a somewhat gravelly till to almost pure sand.

For the improvement of this type, the addition of organic matter and nitrogen is very essential, and limestone should be applied liberally for the best results with legumes. The porous subsoil affords such a deep feeding range for plant roots that the addition of phosphorus is not likely to be necessary or profitable.

Yellow-Gray Sandy Loam on Gravel (1064.4)

Yellow-gray sandy loam on gravel occurs only in the northwestern part of the county, and there in limited areas. The type differs but little from yellow-gray sandy loam except that it contains much more gravel in the subsoil and for that reason is less desirable. It occupies 1.48 square miles, or .3 percent of the entire area of the county. The stratum of gravel varies a great deal, both as to depth and physical composition. In depth it varies from 12 to 30 inches; in composition it is sandy, or a sand in some places, and in others a mixture of sand, gravel, and small stones not over two inches in diameter.

The management of this type should be the same as for the yellow-gray sandy loam. Alfalfa does fairly well on this type, and sweet clover would do equally well.

Dune Sand (1081 *and* 1281)

Dune sand is found in the vicinity of Fox Lake, and also along the old lake shore north of Waukegan. It covers 1.47 square miles. Its presence is due to the action of wind, and possibly the waves, in piling the sand up from the lake shore. The surface soil contains about 2.25 percent of organic matter, while the subsurface has about .8 percent.

In the management of this type, limestone should be applied and legume crops should be prominent in the rotation unless large amounts of organic matter can be added in some other form. The only other addition suggested is potassium, but this should not be applied on a large scale unless found profitable by careful trial on small areas.

For results from field experiments on sand soil, see pages 246 to 249 of Bulletin 123 of this station.[1] In the experiments there described (conducted in Tazewell county), the average value of the increase per acre per annum was $12.12 from nitrogen, $2.96 from potassium (costing $2.50), and 4 cents from phosphorus, the order of crops being corn, corn, oats, wheat, corn, corn. The nitrogen applied cost $15 in commercial form, but of course by growing legume crops, which are worth raising for their own sake, that element may be secured from the air without cost.

Gravelly Loam (1090 *and* 1290)

Gravelly loam occurs principally in the morainal regions of the northwest part of the Lake county, altho some small areas are found in other parts. The total area aggregates 611 acres, or .2 percent of the area of the county.

The surface soil is composed of a large amount of gravel, in many cases amounting to 60 or 70 percent. Occasionally small stones an inch or two in diameter are found mixed with the gravel. The organic-matter content amounts to approximately 3 percent, or 30 tons per acre. The subsurface soil contains about one-fourth as much as the surface.

This type is of very little agricultural significance. The treatment recommended is the same as that for yellow-gray sandy loam (1064). It may well be left in permanent pasture.

(c) TERRACE SOILS

Terrace soils occur along streams and were formed at a time when the streams were much larger than at present and carried large amounts of coarse material, such as sand and gravel. This overloading of the streams caused deposition along their courses which resulted in the formation of terraces, bench lands, or second bottom lands. Fine material, later deposited over this sand and gravel, forms the present soil.

Brown Silt Loam over Gravel (1527)

Brown silt loam over gravel is found along the Des Plaines river near the southern part of the county where the stream formed its widest terrace. The deposit of gravel here is not very deep, but it furnishes a very effective means for the natural drainage of these areas. This type occupies 1.85 square miles.

The surface soil, 0 to 6⅔ inches, is a brown silt loam, with some sand, but rarely containing enough to make it a sandy loam. The average amount of organic matter present is 5.4 percent, or 54 tons per acre.

The subsurface soil consists of a brown silt loam, becoming yellow at about 16 inches and passing into the subsoil at a depth of 18 inches. The subsurface stratum contains about 2.5 percent of organic matter.

The subsoil varies a great deal, in some cases containing a considerable amount of sand and fine gravel. It is generally a yellow clayey silt, pervious, and well drained. The depth to the gravel varies from 38 to 48 inches. It consists of a mixture of medium and fine gravel with some coarse sand.

This type requires practically the same management as the brown silt loam,

[1]Bulletin 123 may be had from the Experiment Station upon request.

altho in some cases there may be more need of organic matter than in some phases of the brown silt loam. Alfalfa should do well on this type.

Yellow-Gray Sandy Loam on Gravel (1564.4)

Yellow-gray sandy loam on gravel occurs only along the Des Plaines river and is limited largely to the east side of this stream. The total area is 2.25 square miles.

The surface soil, 0 to 6⅔ inches, varies in color from a yellow to a gray, and in texture from a loam to a sand. These variations are so limited in area and so badly mixed that it is impossible to represent them on the map. In some places there are slight ridges that indicate low dunes; these give rise to a very sandy phase.

The subsurface stratum is as variable as the surface. In small areas the subsurface is a sandy clay or sandy clay loam, while in others it is a yellow sand. The organic-matter content of the subsurface is higher in the more silty or clayey parts, but in the more sandy phase it contains almost no organic matter.

The subsoil varies in different parts of the Des Plaines valley. In the northern part it is decidedly gravelly, while in the southern, sand prevails. The depth to the sand or gravelly stratum varies from over 30 inches in many places to less than 15 inches in others.

In the southern half of the county this type is not under cultivation, but is almost entirely covered with a young growth of forest trees. Where it is under cultivation, the treatment should be about the same as for the yellow-gray silt loam, except as regards phosphorus. With the porous character of the soil and subsoil, and the extensive feeding range thus afforded plants, the supply of phosphorus naturally contained in this soil should be adequate for large crops.

Brown Sandy Loam on Gravel (1560.4)

Brown sandy loam on gravel is found principally along the Des Plaines river and is similar to yellow-gray sandy loam on gravel except that the forests that have recently grown up here have not reduced the organic-matter content to such a low amount. Part of the type in the southern part of the county has never been covered with forest. In topography the type shows a slight ridging, due to the action of wind in forming sand dunes or of the water in forming bars. The total area is 2.4 square miles, or .5 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, varies in color from a light to a dark brown, almost black, and in texture from a loam to a sandy loam.

The subsurface soil is a light brown loam to sandy loam, having a thickness of 5 to 12 inches with an average of 9 to 10 inches. It passes into the gravelly, sandy subsoil, which is made up of medium and fine gravel, mixed with more or less coarse sand. The depth of the gravel from the surface varies from 14 to 30 inches and even more in small local areas. The bed of gravel itself is probably not over 20 feet in depth in any place, and toward the southern part of the county it is much less than that. In many places it is being taken out for use on roads. The presence of gravel in the subsoil gives excellent drainage to this type, and in seasons of drouth, the crops may suffer because of lack of moisture.

Only the ordinary crops, as a rule, are grown on this type, but it is fairly

well adapted to the growth of alfalfa and deep-rooting crops. Manure, crop residues, or legume crops should be turned under in order to maintain the organic matter and nitrogen, but the addition of phosphorus is not likely to be profitable.

Gravelly Loam on Gravel (1590.4)

Gravelly loam on gravel covers one area of 179 acres in Section 22, Town 46 North, Range 11 East.

The surface soil, 0 to 6⅔ inches, consists of a brown, gravelly loam, the gravel present amounting to 60 to 75 percent. The content of organic matter is about 3 percent. The subsurface stratum contains even a larger amount of gravel than the surface, with a proportionately smaller amount of organic matter. A sample could not be obtained to a depth of more than 20 inches. The subsoil consists of various grades of gravel mixed with a few small stones.

This is a very poor type of soil, owing to the fact that it does not have much power for retaining moisture in times of drouth, and the plant food leaches out readily. The liberal use of legume crops and organic manures is advised.

(d) SWAMP AND BOTTOM-LAND SOILS

Deep Peat (1401)

Deep peat is found in nearly all parts of Lake county, occurring on the old beach of Lake Michigan, in the bottom lands of the streams, in the depressions of the moraines, and around the margins of many of the lakes. The total area is 38.1 square miles, 24,382 acres, or 7.89 percent of the area of the county. The deep peat is formed by the growth of both grasses and mosses. In one area in Section 35, Town 46 North, Range 10 East, the peat was found to be forming entirely by the accumulation of the sphagnum moss, independent of the growth of grasses; in other areas, both grasses and mosses contribute to the deposit.

The surface soil, 0 to 6⅔ inches, is a black or brown peat, more or less decomposed. The drained areas have undergone greater decomposition because of better aeration, while the moss-covered or grass-covered peat of the undrained areas has changed but little. The content of organic matter varies from 61 to 77 percent, with an average of 70.5 percent.

The subsurface soil, 6⅔ to 20 inches, consists of black or brown peat that usually shows the texture of the material from which it was produced.

The subsoil, from 20 to 40 inches, is usually a brown peat, altho in some small areas sand or silty material may form the subsoil below 30 inches. This latter phase is almost invariably drab in color, due to deoxidation by organic acids.

Because of lack of drainage, this type of soil in Lake county has not been largely cultivated, except in the small areas. It does, however, supply a large amount of hay that is used to a considerable extent for packing ice in the large ice houses on the shores of the lakes. As a rule, it is not desirable to attempt to drain this type by means of tiles unless they can be laid deep enough to place them in the clayey or silty subsoil. Tiles laid in peat soon get out of line.

As shown in Table 2, deep peat contains in one million pounds of surface soil about 32,000 pounds of nitrogen, 1,500 pounds of phosphorus, and 3,900

pounds of potassium. This shows in the surface 6⅔ inches of an acre nearly five times as much nitrogen as the brown silt loam prairie. In phosphorus content these two soil types are about equal, but the peat contains less than one-tenth as much potassium as the brown silt loam. Thus the total supply of potassium in the peat to a depth of 7 inches (3,900 pounds) would be equivalent to the potassium requirement (73 pounds) of a hundred-bushel crop of corn for only 53 years; or if the equivalent of only one-fourth of one percent of this is annually available, in accordance with the rough estimate suggested in Bulletin 123, then about 10 pounds of potassium would be liberated annually, or sufficient for about 14 bushels of corn per acre.

In Table 14 are given all results obtained from the Manito (Mason county) experiment field on deep peat, which was begun in 1902 and discontinued after 1905. The plots in this field were one acre[1] each in size, 2 rods wide and 80 rods long. Untreated half-rod division strips were left between the plots, which, however, were cropped the same as the plots.

The results of four years' tests, as given in Table 14, are in complete harmony with the information furnished by the chemical composition of peat soil as compared with that of ordinary normal soils. Where potassium was applied, the yield was from three to four times as large as where nothing was applied. Where approximately equal money values of kainit and potassium chlorid were applied, slightly greater yields were obtained with the potassium chlorid, which, however, supplied about one-third more potassium than the kainit. On the other hand, either material furnished more potassium than was required by the crops produced.

The use of 700 pounds of sodium chlorid (common salt) produced no appreciable increase over the best untreated plots, indicating that where potassium is itself actually deficient, salts of other elements cannot take its place.

Applications of 2 tons per acre of ground limestone produced no increase in the corn crops, either when applied alone or in combination with kainit, either the first year or the second.

TABLE 14.—CORN YIELDS IN SOIL EXPERIMENTS, MANITO FIELD; TYPICAL DEEP PEAT SOIL
(Bushels per acre)

Plot No.	Soil treatment for 1902	Corn 1902	Corn 1903	Soil treatment for 1904	Corn 1904	Corn 1905	Four crops
1	None	10.9	8.1	None	17.0	12.0	48.0
2	None	10.4	10.4	Limestone, 4000 lbs.	12.0	10.1	42.9
3	Kainit, 600 lbs.	30.4	32.4	Limestone, 4000 lbs.; Kainit, 1200 lbs.	49.6	47.3	159.7
4	Kainit, 600 lbs.; Acidulat'd bone, 350 lb.	30.3	33.3	Kainit, 1200 lbs.; Steamed bone, 395 lbs.	53.5	47.6	164.7
5	Potassium chlorid, 200 lbs.	31.2	33.9	Potassium chlorid, 400 lbs.	48.5	52.7	166.3
6	Sodium chlorid, 700 lbs.	11.1	13.1	None	24.0	22.1	70.3
7	Sodium chlorid, 700 lbs.	13.3	14.5	Kainit, 1200 lbs.	44.5	47.3	
8	Kainit, 600 lbs.	36.8	37.7	Kainit, 600 lbs.	44.0	46.0	164.5
9	Kainit, 300 lbs.	26.4	25.1	Kainit, 300 lbs.	41.5	32.9	125.9
10	None	14.9[1]	14.9	None	26.0	13.6	69.4

[1]Estimated from 1903; no yield was taken in 1902 because of a misunderstanding.

[1]In 1904 the yields were taken from quarter-acre plots because of severe insect injury on the other parts of the field.

Reducing the application of kainit from 600 to 300 pounds for each two-year period, reduced the yield of corn from 164.5 to 125.9 bushels. The two applications of 300 pounds of kainit (Plot 9) furnished 60 pounds of potassium for the four years, an amount sufficient for 84 bushels of corn (grain and stalks). Attention is called to the fact that this is practically the difference between the yield of Plot 9 (125.9 bushels) and the yield obtained from Plot 2 (42.9 bushels), the poorest untreated plot.

Medium Peat on Clay (1402)

Medium peat on clay occurs in low, swampy areas, where the peat has not developed to a greater thickness than 30 inches. The total area is 640 acres, equivalent to 1 square mile, or .21 percent of the area of the county.

The surface, 0 to 6⅔ inches, is a brown or black peat, the decomposition varying with cultivation and drainage.

The subsurface, from 6⅔ inches to the depth of the peat, is usually a brownish peat that has not undergone a great amount of decomposition. In the classification used by this station, medium peat extends from 12 to 30 inches in depth, and in most areas the subsurface is usually taken as extending to the silty, clayey, or sandy layer. This gives a large variation in the thickness of the subsurface, but it is sampled to a depth of 20 inches.

The subsoil in this type consists of a silty clay and almost invariably is of light drab or bluish color, owing to deoxidation of iron by organic acids.

The treatment advised for this type is the same as for deep peat (1401), but thoro trials should be made with potassium in advance of extensive use. Drainage is an easier matter because tile may usually be placed in the clay.

Medium Peat on Sand (1402.2)

Medium peat on sand is found only on the old beach of Lake Michigan north of Waukegan, and here in very limited areas large enough to map. The total area is 284 acres.

The surface soil, 0 to 6⅔ inches, is a brownish, somewhat decomposed peat mixed with more or less sand.

The subsurface extends to a depth of 12 to 20 inches, passing into a drab-colored sand that continues to an indefinite depth. Practically none of this is under cultivation, altho some of it is used for pasture. Potassium is the only material suggested for trial applications.

Shallow Peat on Clay (1403)

Shallow peat on clay occurs in small areas on the upland and is usually not very uniform. The total area is 371 acres.

The surface soil, 0 to 6⅔ inches, consists of a dark, peaty material mixed with more or less sand, silt, or clay. It varies from pure peat to a very black silt or clay loam. Very few of these areas are under cultivation, but are mostly in pasture. The tramping of cattle has produced hummocks, which vary in height from 4 to 12 inches. An illustration of these is shown in Plate 9.

The subsurface soil is usually a brown silt loam, changing into a drab or bluish color at 12 to 16 inches in depth.

The subsoil is of the mottled drabbish or yellowish color and usually contains some fragments of limestone. Alkali patches are of frequent occurrence.

The first requirement of this type is good drainage. Where the surface is deficient in potassium, deeper plowing will bring abundance of it from the subsurface to be incorporated with the plowed soil.

Peaty Loam (1410)

Peaty loam is found in small areas in the depressions on the high terrace of Lake Michigan in the northeast part of the county. There is also one larger area in a broad valley west of Lake Bluff. The total area is not large, amounting to only 2.35 square miles, or .49 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, is a black, peaty loam. The amount of organic matter and sand varies in different areas, the organic matter varying from 10 to 25 percent or even more.

The subsurface soil is quite variable. In some areas it is a drabbish or bluish sand mixed with a variable amount of organic matter; in others it is a brown sandy loam; while in others it is clayey or silty.

The subsoil varies from a sand to a sand containing a considerable amount of silt and clay.

The first requirement of this type is good drainage. Some areas may require the application of potassium in order to produce well. This is true especially of those areas where the soil contains little or no clay. Alkali is frequently present in sufficient quantities to do great injury to crops, more particularly to

PLATE 9.—HUMMOCKS ON "BOG" LAND

corn. The alkali consists chiefly of harmless carbonate (limestone) with smaller amounts of injurious magnesium carbonate.

In some cases these peaty soils actually contain a good percentage of total potassium, more commonly in the subsurface or subsoil but sometimes in the surface soil also; and yet the untreated soil may be unproductive, while the addition of potassium salts may produce large and very profitable increases in the yield of corn, oats, etc. In pot-culture experiments we have even been able by the addition of potassium sulfate to correct to a considerable extent the injurious property of magnesium carbonate that has been purposely applied to ordinary brown silt loam prairie soil known to contain abundance of available potassium. These facts are mentioned here because the Experiment Station recommends, tentatively, the application of potassium salt to all classes of peaty and alkali soils that are unproductive after being well drained, whenever the supply of farm manure is insufficient. It should be understood that plenty of farm manure, preferably quick-acting, or readily decomposable, manure, such as horse manure, will supply potassium and thus accomplish everything that potassium salts can accomplish; on some swamp soils manure produces good results even where potassium is without effect.

Black Mixed Loam (1450)

Black mixed loam occurs in many of the low, swampy regions where organic matter has not accumulated sufficiently for the formation of peats. The morainal areas contain large numbers of small ponds, in which this type has developed, but they are too small to be shown on the map. The total area of this type is 19.72 square miles, 12,622 acres, or 4.09 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, varies from a peat to a black clay, black silt, or black sandy loam. The areas of these different phases are so small, however, and so badly mixed, that it is practically impossible to make any satisfactory separation of them into distinct types. For this reason the type is called black mixed loam. The content of organic matter varies from 6 to 20 percent.

The subsurface soil varies to a less extent than the surface. It is generally a dark silt or clay loam with some sand and gravel to a depth of 14 to 16 inches.

The subsoil varies from a drab to a yellow clayey silty material that is made up largely of boulder clay. Many limestone gravels are found in this stratum.

On the surface of this type are found many glacial boulders, mostly granites, that have either been left when the other material has been removed by water, or been brought to the surface by the action of frost. In many cases they are so numerous that cultivation would be impossible without removing them. They vary in size from a few inches to several feet in diameter.

In the management of this type, the first essential is thoro drainage. The variability of the soil makes it rather difficult to suggest any treatment that will apply to the type as a whole. It may be found that some areas will need applications of potassium. This is true of the small peaty areas as well as the alkali spots that are quite common in the type. Comparatively little of this type is under cultivation; nearly all of it is either in pasture or meadow.

The tramping of stock on this type produces hummocks, or "bogs," as they are frequently called by the farmers of this vicinity. The height of these may

be increased by freezing and thawing to 12 or 15 inches. Driving over such an area as this with implements is practically impossible. A "bog cutter," consisting of a series of either straight or curved knives, is used for reducing the hummocks before plowing. (See Plate 9.)

Mixed Loam (*Bottom Land*) (1454)

Mixed loam occurs along the streams. In many instances it is very much like the black mixed loam (1450); as a rule, however, it has received sufficient deposit from overflow to give it a more uniform character. The total area of this type is 8.51 square miles, 5,446 acres, or 1.76 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, is brown to black in color, varying in texture from a silt loam to a sandy loam. The streams of this county overflow less than in other parts of the state because the numerous lakes act as reservoirs giving a steady flow. The lakes also act as silt basins, in which the sediment settles. For these reasons there is less sediment carried and deposited on the flood plains. The amount of organic matter varies from 5 to 10 percent with an average of 7.7 percent, or 77 tons per acre.

The subsurface soil, 6⅔ to 20 inches, varies from a brown silt loam to a brown sandy loam, and is a little lighter in color than the surface soil.

The subsoil varies from light brown to a yellowish or drabbish color, indicating that sufficient time has elapsed for the formation of a distinct subsoil. This occurs only where sedimentation takes place slowly.

Because of lack of drainage, comparatively little of this type is under cultivation. It makes good pasture land, and possibly that will be its principal use for years to come. Drainage is the first thing necessary. Where overflow occurs, high fertility is likely to be maintained.

Beach Sand (1482)

Beach sand, which might be called mixed sand and peat, extends from Waukegan to the state line and represents the beach of Lake Chicago. Its greatest width is about one mile. The area consists of a large number of sand ridges with peat deposits between them. These ridges are usually but a few rods wide, and still fewer rods apart, and the peat is represented by such small areas that it is practically impossible to indicate them on the map. The sand in some places has a covering of weeds, black oak, or stunted white pine. The soil is so variable here that it is practically impossible to give a description of the different strata, since in many cases a rod either way would mean an entire change of type. If drained, the treatment likely to be profitable will be suggested by a study of "dune sand" and "deep peat," described in the preceding pages.

LAKES

Lake county contains 47 lakes, having a total area of 18 square miles, 11,512 acres, or 3.72 percent of the entire area of the county. Many of these lakes have swampy shores, which fact indicates that a gradual extinction is going on and that in time they will be filled with organic deposits. Many of the peaty areas are without doubt extinct lakes that have been filled by the accumulation of organic matter.

APPENDIX

A study of the soil map and the tabular statements concerning crop requirements, the plant-food content of the different soil types, and the actual results secured from definite field trials with different methods or systems of soil improvement, and a careful study of the discussion of general principles and of the descriptions of individual soil types, will furnish the most necessary and useful information for the practical improvement and permanent preservation of the productive power of every kind of soil on every farm in the county.

More complete information concerning the most extensive and important soil types in the great soil areas in all parts of Illinois is contained in Bulletin 123, "The Fertility in Illinois Soils," which contains a colored general soil-survey map of the entire state.

Other publications of general interest are:

Bulletin No. 76, "Alfalfa on Illinois Soils"
Bulletin No. 94, "Nitrogen Bacteria and Legumes"
Bulletin No. 115, "Soil Improvement for the Worn Hill Lands of Illinois"
Bulletin No. 125, "Thirty Years of Crop Rotation on the Common Prairie Lands of Illinois"
Circular No. 82, "Physical Improvement of Soils"
Circular No. 110, "Ground Limestone for Acid Soils"
Circular No. 127, "Shall We Use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils?"
Circular No. 129, "The Use of Commercial Fertilizers"
Circular No. 149, "Results of Scientific Soil Treatment" and "Methods and Results of Ten Years' Soil Investigation in Illinois"
Circular No. 165, "Shall We Use 'Complete' Commercial Fertilizers in the Corn Belt?"
Circular No. 167, "The Illinois System of Permanent Fertility"

NOTE.—Information as to where to obtain limestone, phosphate, bone meal, and potassium salts, methods of application, etc., will also be found in Circulars 110 and 165.

SOIL SURVEY METHODS

The detail soil survey of a county consists essentially of ascertaining, and indicating on a map, the location and extent of the different soil types; and, since the value of the survey depends upon its accuracy, every reasonable means is employed to make it trustworthy. To accomplish this object three things are essential: first, careful, well-trained men to do the work; second, an accurate base map upon which to show the results of the work; and, third, the means necessary to enable the men to place the soil-type boundaries, streams, etc., accurately upon the map.

The men selected for the work must be able to keep their location exactly and to recognize the different soil types, with their principal variations and limits, and they must show these upon the maps correctly. A definite system is employed in checking up this work. As an illustration, one soil expert will survey and map a strip 80 rods or 160 rods wide and any convenient length, while his associate will work independently on another strip adjoining this area, and, if the work is correctly done, the soil type boundaries must match up on the line between the two strips.

An accurate base map for field use is absolutely necessary for soil mapping. The base maps are made on a scale of one inch to the mile. The official data of the original or subsequent land survey are used as a basis in the construction of these maps, while the most trustworthy county map available is used in

locating temporarily the streams, roads, and railroads. Since the best of these published maps have some inaccuracies, the location of every road, stream, and railroad must be verified by the soil surveyors, and corrected if wrongly located. In order to make these verifications and corrections, each survey party is provided with an odometer for measuring distances, and a plane table for determining directions of angling roads, railroads, etc.

Each surveyor is provided with a base map of the proper scale, which is carried with him in the field; and the soil-type boundaries, ditches, streams, and necessary corrections are placed in their proper locations upon the map while the mapper is on the area. Each section, or square mile, is divided into 40-acre plots on the map, and the surveyor must inspect every ten acres and determine the type or types of soil composing it. The different types are indicated on the map by different colors, pencils for this purpose being carried in the field.

A small auger 40 inches long forms for each man an invaluable tool with which he can quickly secure samples of the different strata for inspection. An extension for making the auger 80 inches long is carried by each party, so that any peculiarity of the deeper subsoil layers may be studied. Each man carries a compass to aid in keeping directions. Distances along roads are measured by an odometer attached to the axle of the vehicle, while distances in the field off the roads are determined by pacing, an art in which the men become expert by practice. The soil boundaries can thus be located with as high a degree of accuracy as can be indicated by pencil on the scale of one inch to the mile.

SOIL CHARACTERISTICS

The unit in the soil survey is the soil type, and each type possesses more or less definite characteristics. The line of separation between adjoining types is usually distinct, but sometimes one type grades into another so gradually that it is very difficult to draw the line between them. In such exceptional cases, some slight variation in the location of soil-type boundaries is unavoidable.

Several factors must be taken into account in establishing soil types. These are (1) the geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial, or cumulose; (2) the topography, or lay of the land; (3) the native vegetation, as forest or prairie grasses; (4) the structure, or the depth and character of the surface, subsurface, and subsoil; (5) the physical, or mechanical, composition of the different strata composing the soil, as the percentages of gravel, sand, silt, clay, and organic matter which they contain; (6) the texture, or porosity, granulation, friability, plasticity, etc.; (7) the color of the strata; (8) the natural drainage; (9) the agricultural value, based upon its natural productiveness; (10) the ultimate chemical composition and reaction.

The common soil constituents are indicated in the following outline:

Soil constituents	Organic matter	Comprising undecomposed and partially decayed vegetable or organic material	
	Inorganic matter	Clay	.001 mm.[1] and less
		Silt	.001 mm. to .03 mm.
		Sands	.03 mm. to 1. mm.
		Gravel	1. mm. to 32 mm.
		Stones	32. mm. and over

Further discussion of these constituents is given in Circular 82.

[1]25 millimeters equal 1 inch.

Groups of Soil Types

The following gives the different general groups of soils:

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or silt.

Peaty loams—15 to 35 percent of organic matter mixed with much sand. Some silt and a little clay may be present.

Mucks—15 to 35 percent of partly decomposed organic matter mixed with much clay and silt.

Clays—Soils with more than 25 percent of clay, usually mixed with much silt.

Clay loams—Soils with from 15 to 25 percent of clay, usually mixed with much silt and some sand.

Silt loams—Soils with more than 50 percent of silt and less than 15 percent of clay, mixed with some sand.

Loams—Soils with from 30 to 50 percent of sand mixed with much silt and a little clay.

Sandy loams—Soils with from 50 to 75 percent of sand.

Fine sandy loams—Soils with from 50 to 75 percent of fine sand mixed with much silt and little clay.

Sands—Soils with more than 75 percent of sand.

Gravelly loams—Soils with 25 to 50 percent of gravel with much sand and some silt.

Gravels—Soils with more than 50 percent of gravel and much sand.

Stony loams—Soils containing a considerable number of stones over one inch in diameter.

Rock outcrop—Usually ledges of rock having no direct agricultural value.

More or less organic matter is found in all the above groups.

Supply and Liberation of Plant Food

The productive capacity of land in humid sections depends almost wholly upon the power of the soil to feed the crop; and this, in turn, depends both upon the stock of plant food contained in the soil and upon the rate at which it is liberated, or rendered soluble and available for use in plant growth. Protection from weeds, insects, and fungous diseases, tho exceedingly important, is not a positive but a negative factor in crop production.

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but the rate of liberation is governed by many factors, some of which may be controlled by the farmer, while others are largely beyond his control. Chief among the important controllable factors which influence the liberation of plant food are limestone and decaying organic matter, which may be added to the soil by direct application of ground limestone and farm manure. Organic matter may be supplied also by green-manure crops and crop residues, such as clover, cowpeas, straw, and corn stalks. The rate of decay of organic matter depends largely upon its age and origin,

and it may be hastened by tillage. The chemical analysis shows correctly the total organic carbon, which represents, as a rule, but little more than half the organic matter; so that 20,000 pounds of organic carbon in the plowed soil of an acre correspond to nearly 20 tons of organic matter. But this organic matter consists largely of the old organic residues that have accumulated during the past centuries because they were resistant to decay, and 2 tons of clover or cowpeas plowed under may have greater power to liberate plant food than the 20 tons of old, inactive organic matter. The recent history of the individual farm or field must be depended upon for information concerning recent additions of active organic matter, whether in applications of farm manure, in legume crops, or in grass-root sods of old pastures.

Probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that with the normal rainfall of Illinois the productive power of the land depends primarily upon the stock of plant food contained in the soil and upon the rate at which it is liberated, just as the success of the merchant depends primarily upon his stock of goods and the rapidity of sales. In both cases the stock of any commodity must be increased or renewed whenever the supply of such commodity becomes so depleted as to limit the success of the business, whether on the farm or in the store.

As the organic matter decays, certain decomposition products are formed, including much carbonic acid, some nitric acid, and various organic acids, and these have power to act upon the soil and dissolve the essential mineral plant foods, thus furnishing soluble phosphates, nitrates, and other salts of potassium, magnesium, calcium, etc., for the use of the growing crop.

As already explained, fresh organic matter decomposes much more rapidly than old humus, which represents the organic residues most resistant to decay and which consequently has accumulated in the soil during the past centuries. The decay of this old humus can be hastened both by tillage, which maintains a porous condition and thus permits the oxygen of the air to enter the soil more freely and to effect the more rapid oxidation of the organic matter, and also by incorporating with the old, resistant residues some fresh organic matter, such as farm manure, clover roots, etc., which decay rapidly and thus furnish or liberate organic matter and inorganic food for bacteria, the bacteria, under such favorable conditions, appearing to have power to attack and decompose the old humus. It is probably for this reason that peat, a very inactive and inefficient fertilizer when used by itself, becomes much more effective when composted with fresh farm manure; so that two tons of the compost[1] may be worth as much as two tons of manure, but if applied separately, the peat has little value. Bacterial action is also promoted by the presence of limestone.

[1]In his book, "Fertilizers," published in 1839, Cuthbert W. Johnson reported such compost to have been much used in England and to be valued as highly, "weight for weight, as farm-yard dung."

The condition of the organic matter of the soil is indicated more or less definitely by the ratio of carbon to nitrogen. As an average, the fresh organic matter incorporated with soils contains about twenty times as much carbon as nitrogen, but the carbohydrates ferment and decompose much more rapidly than the nitrogenous matter; and the old resistant organic residues, such as are found in normal subsoils, commonly contain only five or six times as much carbon as nitrogen. Soils of normal physical composition, such as loam, clay loam, silt loam, and fine sandy loam, when in good productive condition, contain about twelve to fourteen times as much carbon as nitrogen in the surface soil; while in old, worn soils that are greatly in need of fresh, active, organic manures, the ratio is narrower, sometimes falling below ten of carbon to one of nitrogen. Soils of cut-over or burnt-over timber lands sometimes contain so much partially decayed wood or charcoal as to destroy the value of the nitrogen-carbon ratio for the purpose indicated. (Except in newly made alluvial soils, the ratio is usually narrower in the subsurface and subsoil than in the surface stratum.)

It should be kept in mind that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all agricultural plants, only one (hydrogen) from water, and seven from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes), in case the amount liberated from the soil is insufficient; but even these plants (which include only the clovers, peas, beans, and vetches, among our common agricultural plants) secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron, and sulfur), and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Plants are made of plant-food elements in just the same sense that a building is made of wood and iron, brick, stone, and mortar. Without materials, nothing material can be made. The normal temperature, sunshine, rainfall, and length of season in central Illinois are sufficient to produce 50 bushels of wheat per acre, 100 bushels of corn, 100 bushels of oats, and 4 tons of clover hay; and, where the land is properly drained and properly tilled, such crops would frequently be secured *if the plant foods were present in sufficient amounts and liberated at a sufficiently rapid rate to meet the absolute needs of the crops.*

CROP REQUIREMENTS

The accompanying table shows the requirements of wheat, corn, oats, and clover for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally in sufficient abundance compared with the amounts needed by plants, so that they are never known to limit the yield of general farm crops grown under normal conditions.)

TABLE A.—PLANT FOOD IN WHEAT, CORN, OATS, AND CLOVER

Produce: Kind	Produce: Amount	Nitrogen	Phosphorus	Potassium	Magnesium	Calcium
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Wheat, grain........	50 bu.	71	12	13	4	1
Wheat straw........	2½ tons	25	4	45	4	10
Corn, grain..........	100 bu.	100	17	19	7	1
Corn stover.........	3 tons	48	6	52	10	21
Corn cobs..........	½ ton	2		2		
Oats, grain..........	100 bu.	66	11	16	4	2
Oat straw..........	2½ tons	31	5	52	7	15
Clover seed.........	4 bu.	7	2	3	1	1
Clover hay.........	4 tons	160	20	120	31	117
Total in grain and seed..................		244[1]	42	51	16	4
Total in four crops......................		510[1]	77	322	68	168

[1]These amounts include the nitrogen contained in the clover seed or hay, which, however, may be secured from the air.

To be sure, these are large yields, but shall we try to make possible the production of yields only half or a quarter as large as these, or shall we set as our ideal this higher mark, and then approach it as nearly as possible with profit? Among the four crops, corn is the largest, with a total yield of more than six tons per acre; and yet the 100-bushel crop of corn is often produced on rich pieces of land in good seasons. In very practical and profitable systems of farming, the Illinois Experiment Station has produced, as an average of the six years 1905 to 1910, a yield of 87 bushels of corn per acre in grain farming (with limestone and phosphorus applied, and with crop residues and legume crops turned under), and 90 bushels per acre in live-stock farming (with limestone, phosphorus, and manure).

The importance of maintaining a rich surface soil cannot be too strongly emphasized. This is well illustrated by data from the Rothamsted Experiment Station, the oldest in the world. On Broadbalk field, where wheat has been grown since 1844, the average yields for the ten years 1892 to 1901 were 12.3 bushels per acre on Plot 3 (unfertilized) and 31.8 bushels on Plot 7 (well fertilized), but the amounts of both nitrogen and phosphorus in the subsoil (9 to 27 inches) were distinctly greater in Plot 3 than in Plot 7, thus showing that the higher yields from Plot 7 were due to the fact that the plowed soil had been enriched. In 1893 Plot 7 contained per acre in the surface soil (0 to 9 inches) about 600 pounds more nitrogen and 900 pounds more phosphorus than Plot 3. Even a rich subsoil has little value if it lies beneath a worn-out surface.

METHODS OF LIBERATING PLANT FOOD

Limestone and decaying organic matter are the principal materials which the farmer can utilize most profitably to bring about the liberation of plant food. The limestone corrects the acidity of the soil and thus encourages the development not only of the nitrogen-gathering bacteria which live in the nodules on the roots of clover, cowpeas, and other legumes, but also the nitrifying bacteria, which have power to transform the insoluble and unavailable organic

nitrogen into soluble and available nitrate nitrogen. At the same time, the products of this decomposition have power to dissolve the minerals contained in the soil, such as potassium and magnesium, and also to dissolve the insoluble phosphate and limestone which may be applied in low-priced forms.

Tillage, or cultivation, also hastens the liberation of plant food by permitting the air to enter the soil and burn out the organic matter; but it should never be forgotten that tillage is wholly destructive, that it adds nothing whatever to the soil, but always leaves it poorer. Tillage should be practiced so far as is necessary to prepare a suitable seed bed for root development and also for the purpose of killing weeds, but more than this is unnecessary and unprofitable in seasons of normal rainfall; and it is much better actually to enrich the soil by proper applications or additions, including limestone and organic matter (both of which have power to improve the physical condition as well as to liberate plant food) than merely to hasten soil depletion by means of excessive cultivation.

PERMANENT SOIL IMPROVEMENT

The best and most profitable methods for the permanent improvement of the common soils of Illinois are as follows:

(1) If the soil is acid, apply at least two tons per acre of ground limestone, preferably at times magnesian limestone ($CaCO_3MgCO_3$), which contains both calcium and magnesium and has slightly greater power to correct soil acidity, ton for ton, than the ordinary calcium limestone ($CaCO_3$); and continue to apply about two tons per acre of ground limestone every four or five years. On strongly acid soils, or on land being prepared for alfalfa, five tons per acre of ground limestone may well be used for the first application.

(2) Adopt a good rotation of crops, including a liberal use of legumes, and increase the organic matter of the soil either by plowing under the legume crops and other crop residues (straw and corn stalks), or by using for feed and bedding practically all the crops raised and returning the manure to the land with the least possible loss. No one can say in advance what will prove to be the best rotation of crops, because of variation in farms and farmers, and in prices for produce, but the following are suggested to serve as models or outlines:

First year, corn.
Second year, corn.
Third year, wheat or oats (with clover or clover and grass).
Fourth year, clover or clover and grass.
Fifth year, wheat and clover or grass and clover.
Sixth year, clover or clover and grass.

Of course there should be as many fields as there are years in the rotation. In grain farming, with small grain grown the third and fifth years, most of the coarse products should be returned to the soil, and the clover may be clipped and left on the land (only the clover seed being sold the fourth and sixth years); or, in live-stock farming, the field may be used three years for timothy and clover pasture and meadow if desired. The system may be reduced to a five-year rotation by cutting out either the second or the sixth year, and to a four-year system by omitting the fifth and sixth years.

With two years of corn, followed by oats with clover-seeding the third year, and by clover the fourth year, all produce can be used for feed and bedding if other land is available for permanent pasture. Alfalfa may be grown on a fifth field for four or eight years, which is to be alternated with one of the four; or the alfalfa may be moved every five years, and thus rotated over all five fields every twenty-five years.

Other four-year rotations more suitable for grain farming are:

Wheat (and clover), corn, oats, and clover; or corn (and clover), cowpeas, wheat, and clover. (Alfalfa may be grown on a fifth field and rotated every five years, the hay being sold.)

Good three-year rotations are:

Corn, oats, and clover; corn, wheat, and clover; or wheat (and clover), corn (and clover), and cowpeas, in which two cover crops and one regular crop of legumes are grown in three years.

A five-year rotation of (1) corn (and clover), (2) cowpeas, (3) wheat, (4) clover, and (5) wheat (and clover) allows legumes to be seeded four times. Alfalfa may be grown on a sixth field for five or six years in the combination rotation, alternating between two fields every five years, or rotating over all the fields if moved every six years.

To avoid clover sickness it may sometimes be necessary to substitute sweet clover or alsike for red clover in about every third rotation, and at the same time to discontinue its use in the cover-crop mixture. If the corn crop is not too rank, cowpeas or soybeans may also be used as a cover crop (seeded at the last cultivation) in the southern part of the state, and, if necessary to avoid disease, these may well alternate in successive rotations.

For easy figuring it may well be kept in mind that the following amounts of nitrogen are required for the produce named:

1 bushel of oats (grain and straw) requires 1 pound of nitrogen.
1 bushel of corn (grain and stalks) requires 1½ pounds of nitrogen.
1 bushel of wheat (grain and straw) requires 2 pounds of nitrogen.
1 ton of timothy requires 24 pounds of nitrogen.
1 ton of clover contains 40 pounds of nitrogen.
1 ton of cowpeas contains 43 pounds of nitrogen.
1 ton of average manure contains 10 pounds of nitrogen.

The roots of clover contain about half as much nitrogen as the tops, and the roots of cowpeas contain about one-tenth as much as the tops.

Soils of moderate productive power will furnish as much nitrogen to clover (and two or three times as much to cowpeas) as will be left in the roots and stubble. In grain crops, such as wheat, corn, and oats, about two-thirds of the nitrogen is contained in the grain and one-third in the straw or stalks. (See also discussion of "The Potassium Problem," on pages following.)

(3) On all lands deficient in phosphorus (except on those susceptible to serious erosion by surface washing or gullying) apply that element in considerably larger amounts than are required to meet the actual needs of the crops desired to be produced. The abundant information thus far secured shows positively that fine-ground natural rock phosphate can be used successfully and very profitably, and clearly indicates that this material will be the most economical form of phosphorus to use in all ordinary systems of permanent, profitable soil

improvement. The first application may well be one ton per acre, and subsequently about one-half ton per acre every four or five years should be applied, at least until the phosphorus content of the plowed soil reaches 2,000 pounds per acre, which may require a total application of from three to five or six tons per acre of raw phosphate containing 12½ percent of the element phosphorus.

Steamed bone meal and even acid phosphate may be used in emergencies, but it should always be kept in mind that phosphorus delivered in Illinois costs about 3 cents a pound in raw phosphate (direct from the mine in carload lots), but 10 cents a pound in steamed bone meal, and about 12 cents a pound in acid phosphate, both of which cost too much per ton to permit their common purchase by farmers in carload lots, which is not the case with limestone or raw phosphate.

Phosphorus once applied to the soil remains in it until removed in crops, unless carried away mechanically by soil erosion. (The loss by leaching is only about 1½ pounds per acre per annum, so that more than 150 years would be required to leach away the phosphorus applied in one ton of raw phosphate.)

The phosphate and limestone may be applied at any time during the rotation, but a good method is to apply the limestone after plowing and work it into the surface soil in preparing the seed bed for wheat, oats, rye, or barley, where clover is to be seeded; while phosphate is best plowed under with farm manure, clover, or other green manures, which serve to liberate the phosphorus.

(4) Until the supply of decaying organic matter has been made adequate, on the poorer types of upland timber and gray prairie soils some temporary benefit may be derived from the use of a soluble salt or a mixture of salts, such as kainit, which contains both potassium and magnesium in soluble form and also some common salt (sodium chlorid). About 600 pounds per acre of kainit applied and turned under with the raw phosphate will help to dissolve the phosphorus as well as to furnish available potassium and magnesium, and for a few years such use of kainit may be profitable on lands deficient in organic matter, but the evidence thus far secured indicates that its use is not absolutely necessary and that it will not be profitable after adequate provision is made for supplying decaying organic matter, since this will necessitate returning to the soil the potassium contained in the crop residues from grain farming or the manure produced in live-stock farming, and will also provide for the liberating of potassium from the soil. (Where hay or straw is sold, manure should be bought.)

On soils which are subject to surface washing, including especially the yellow silt loam of the upland timber area, and to some extent the yellow-gray silt loam and other more rolling areas, the supply of minerals in the subsurface and subsoil (which gradually renew the surface soil) tends to provide for a low-grade system of permanent agriculture if some use is made of legume plants, as in long rotations with much pasture, because both the minerals and nitrogen are thus provided in some amount almost permanently; but where such lands are farmed under such a system, not more than two or three grain crops should be grown during a period of ten or twelve years, the land being kept in pasture most of the time; and where the soil is acid a liberal use of limestone, as top-dressings if necessary, and occasional reseeding with clovers will benefit both the pasture and indirectly the grain crops.

ADVANTAGE OF CROP ROTATION AND PERMANENT SYSTEMS

It should be noted that clover is not likely to be well infected with the clover bacteria during the first rotation on a given farm or field where it has not been grown before within recent years; but even a partial stand of clover the first time will probably provide a thousand times as many bacteria for the next clover crop as one could afford to apply in artificial inoculation, for a single root-tubercle may contain a million bacteria developed from one during the season's growth.

This is only one of several advantages of the second course of the rotation over the first course. Thus the mere practice of crop rotation is an advantage, especially in helping to rid the land of insects and foul grass and weeds. The clover crop is an advantage to subsequent crops because of its deep-rooting characteristic. The larger applications of organic manures (made possible by the larger crops) are a great advantage; and in systems of permanent soil improvement, such as are here advised and illustrated, more limestone and more phosphorus are provided than are needed for the meager or moderate crops produced during the first rotation, and consequently the crops in the second rotation have the advantage of such accumulated residues (well incorporated with the plowed soil) in addition to the regular applications made during the second rotation.

This means that these systems tend positively toward the making of richer lands. The ultimate analyses recorded in the tables give the absolute invoice of these Illinois soils. They show that most of them are positively deficient only in limestone, phosphorus, and nitrogenous organic matter; and the accumulated information from careful and long-continued investigations in different parts of the United States clearly establishes the fact that in general farming these essentials can be supplied with greatest economy and profit by the use of ground natural limestone, very finely ground natural rock phosphate, and legume crops to be plowed under directly or in farm manure. On normal soils no other applications are absolutely necessary, but, as already explained, the addition of some soluble salt in the beginning of a system of improvement on some of these soils produces temporary benefit, and if some inexpensive salt, such as kainit, is used, it may produce sufficient increase to more than pay the added cost.

THE POTASSIUM PROBLEM

As reported in Illinois Bulletin 123, where wheat has been grown every year for more than half a century at Rothamsted, England, exactly the same increase was produced (5.6 bushels per acre), as an average of the first 24 years, whether potassium, magnesium, or sodium was applied, the rate of application per annum being 200 pounds of potassium sulfate and molecular equivalents of magnesium sulfate and sodium sulfate. As an average of 60 years (1852 to 1911), the yield of wheat was 12.7 bushels on untreated land and 23.3 bushels where 86 pounds of nitrogen and 29 pounds of phosphorus per acre per annum were applied. As further additions, 85 pounds of potassium raised the yield to 31.3 bushels; 52 pounds of magnesium raised it to 29.2 bushels; and 50 pounds of sodium raised it to 29.5 bushels. Where potassium was applied, the wheat crop removed an-

nually an average of 40 pounds of that element in the grain and straw, or three times as much as would be removed in the grain only for such crops as are suggested in Table A. The Rothamsted soil contained an abundance of limestone, but no organic matter was provided except the little in the stubble and roots of the wheat plants.

On another field at Rothamsted the average yield of barley for 60 years (1852 to 1911) was 14.2 bushels on untreated land, 38.1 bushels where 43 pounds of nitrogen and 29 pounds of phosphorus were applied per acre per annum; while the further addition of 85 pounds of potassium, 19 pounds of magnesium, and 14 pounds of sodium (all in sulfates) raised the average yield to 41.5 bushels. Where only 70 pounds of sodium were applied in addition to the nitrogen and phosphorus, the average was 43.0 bushels. Thus, as an average of 60 years, the use of sodium produced 1.8 bushels less wheat and 1.5 bushels more barley than the use of potassium, with both grain and straw removed and no organic manures returned.

In recent years the effect of potassium is becoming much more marked than that of sodium or magnesium, on the wheat crop; but this must be expected to occur in time where no potassium is returned in straw or manure, and no provision made for liberating potassium from the supply still remaining in the soil. If the wheat straw, which contains more than three-fourths of the potassium removed in the wheat crop (see Table A), were returned to the soil, the necessity of purchasing potassium in a good system of farming on such land would be at least very remote, for the supply would be adequately maintained by the actual amount returned in the straw, together with the additional amount which would be liberated from the soil by the action of decomposition products.

While about half the potassium, nitrogen, and organic matter, and about one-fourth the phosphorus contained in manure is lost by three or four months' exposure in the ordinary pile in the barn yard, there is practically no loss if plenty of absorbent bedding is used on cement floors, and if the manure is hauled to the field and spread within a day or two after it is produced. Again, while in average live-stock farming the animals destroy two-thirds of the organic matter and retain one-fourth of the nitrogen and phosphorus from the food they consume, they retain less than one-tenth of the potassium; so that the actual loss of potassium in the products sold from the farm, either in grain farming or in live-stock farming, is wholly negligible on land containing 25,000 pounds or more of potassium in the surface 6⅔ inches.

The removal of one inch of soil per century by surface washing (which is likely to occur wherever there is satisfactory surface drainage and frequent cultivation) will permanently maintain the potassium in grain farming by renewal from the subsoil, provided one-third of the potassium is removed by cropping before the soil is carried away.

From all these facts it will be seen that the potassium problem is not one of addition but of liberation; and the Rothamsted records show that for many years other soluble salts have practically the same power as potassium to increase crop yields in the absence of sufficient decaying organic matter. Whether this

action relates to supplying or liberating potassium for its own sake, or to the power of the soluble salt to increase the availability of phosphorus or other elements, is not known, but where much potassium is removed, as in the entire crops at Rothamsted, with no return of organic residues, probably the soluble salt functions in both ways.

As an average of 112 separate tests conducted in 1907, 1908, 1909, and 1910 on the Fairfield experiment field, an application of 200 pounds of potassium sulfate, containing 85 pounds of potassium and costing $5.10, increased the yield of corn by 9.3 bushels per acre; while 600 pounds of kainit, containing only 60 pounds of potassium and costing $4, gave an increase of 10.7 bushels. Thus, at 40 cents a bushel for corn, the kainit paid for itself; but these results, like those at Rothamsted, were secured where no adequate provision had been made for decaying organic matter.

Additional experiments at Fairfield included an equally complete test with potassium sulfate and kainit on land to which 8 tons per acre of farm manure were applied. As an average of 112 tests with each material, the 200 pounds of potassium sulfate increased the yield of corn by 1.7 bushels, while the 600 pounds of kainit also gave an increase of 1.7 bushels. Thus, where organic manure was supplied, very little effect was produced by the addition of either potassium sulfate or kainit; in part perhaps because the potassium removed in the crops is mostly returned in the manure if properly cared for, and perhaps in larger part because the decaying organic matter helps to liberate and hold in solution other plant-food elements, especially phosphorus.

In laboratory experiments at the Illinois Experiment Station, it has been shown by chemical analysis that potassium salts and most other soluble salts increase the solubility of the phosphorus in soil and in rock phosphate; also that the addition of glucose with rock phosphate in pot-culture experiments increases the availability of the phosphorus, as measured by plant growth, altho the glucose consists only of carbon, hydrogen, and oxygen, and thus contains no plant food of value.

If we remember that, as an average, live stock destroy two-thirds of the organic matter of the food they consume, it it easy to determine from Table A that more organic matter will be supplied in a proper grain system than in a strictly live-stock system; and the evidence thus far secured from older experiments at the University and at other places in the state indicates that if the corn stalks, straw, clover, etc., are incorporated with the soil as soon as practicable after they are produced (which can usually be done in the late fall or early spring), there is little or no difficulty in securing sufficient decomposition in our humid climate to avoid serious interference with the capillary movement of the soil moisture, a common danger from plowing under too much coarse manure of any kind in the late spring of a dry year.

If, however, the entire produce of the land is sold from the farm, as in hay farming or when both grain and straw are sold, of course the draft on potassium will then be so great that in time it must be renewed by some sort of application. As a rule, farmers following this practice ought to secure manure from town, since they furnish the bulk of the material out of which manure is produced.

Calcium and Magnesium

When measured by the actual crop requirements for plant food, magnesium and calcium are more limited in some Illinois soils than potassium. But with these elements we must also consider the loss by leaching. As an average of 90 analyses[1] of Illinois well-waters drawn chiefly from glacial sands, gravels, or till, 3 million pounds of water (about the average annual drainage per acre for Illinois) contained 11 pounds of potassium, 130 of magnesium, and 330 of calcium. These figures are very significant, and it may be stated that if the plowed soil is well supplied with the carbonates of magnesium and calcium, then a very considerable proportion of these amounts will be leached from that stratum. Thus the loss of calcium from the plowed soil of an acre at Rothamsted, England, where the soil contains plenty of limestone, has averaged more than 300 pounds a year as determined by analyzing the soil in 1865 and again in 1905. Practically the same amount of calcium was found, by analyses, in the Rothamsted drainage waters.

Common limestone, which is calcium carbonate ($CaCO_3$), contains, when pure, 40 percent of calcium, so that 800 pounds of limestone are equivalent to 320 pounds of calcium. Where 10 tons per acre of ground limestone were applied at Edgewood, Illinois, the average annual loss during the next ten years amounted to 790 pounds per acre. The definite data from careful investigations seem to be ample to justify the conclusion that where limestone is needed at least 2 tons per acre should be applied every 4 or 5 years.

It is of interest to note that thirty crops of clover of four tons each would require 3,510 pounds of calcium, while the most common prairie land of southern Illinois contains only 3,420 pounds of total calcium in the plowed soil of an acre. (See Soil Report No. 1.) Thus limestone has a positive value on some soils for the plant food which it supplies, in addition to its value in correcting soil acidity and in improving the physical condition of the soil. Ordinary limestone (abundant in the southern and western parts of the state) contains nearly 800 pounds of calcium per ton; while a good grade of dolomitic limestone (the more common limestone of northern Illinois) contains about 400 pounds of calcium and 300 pounds of magnesium per ton. Both of these elements are furnished in readily available form in ground dolomitic limestone.

Physical Improvement of Soils

In the management of most soil types, one very important thing, aside from proper fertilization, tillage, and drainage, is to keep the soil in good physical condition, or good tilth. The constituent most important for this purpose is organic matter. Not only does it impart good tilth to the soil, but it prevents much loss by washing on rolling land, warms the soil by absorption of heat, retains moisture during drouth, furnishes nitrogen for the crop, aids in the liberation of mineral plant food, and prevents the soil from running together badly. This constituent must be supplied to the soil in every practical way, so that the amount may be maintained or even increased. It is being broken down during a large part of the year, and the nitrates produced are used for plant growth.

[1]Reported by Doctor Bartow and associates, of the Illinois State Water Survey.

This breaking down is necessary, but it is also quite necessary that the supply be maintained.

The physical effect of organic matter in the soil is to produce a granulation, or mellowness, very favorable for tillage and the development of plant roots. If continuous cropping takes place, accompanied with the removal of the corn stalks and straw, the amount of organic matter is gradually diminished and a condition of poor tilth will ultimately follow. In many cases this already limits the crop yields. The remedy is to increase the organic-matter content by plowing under crop residues, such as corn stalks, straw, and clover. Selling these products from the farm, burning them, or feeding them and not returning the manure, or allowing a very large part of the manure to be lost before it is returned to the land, all represent bad practice.

One of the chief sources of loss of organic matter in the corn belt is the practice of burning the corn stalks. Could the farmers be made to realize how great a loss this entails, they would certainly discontinue the practice. Probably no form of organic matter acts more beneficially in producing good tilth than corn stalks. It is true that they decay rather slowly, but it is also true that their durability in the soil after partial decomposition is exactly what is needed in the maintenance of an adequate supply of humus.

The nitrogen in a ton of cornstalks is 1½ times that in a ton of manure, and a ton of dry corn stalks incorporated with the soil will ultimately furnish as much humus as 4 tons of average farm manure; but when burned, both the humus-making material and the nitrogen which these stalks contain are destroyed and lost to the soil.

The objection is often raised that when stalks are plowed under they interfere very seriously in the cultivation of corn, and thus indirectly destroy a great deal of corn. If corn stalks are well cut up and then turned under to a depth of 5½ to 6 inches when the ground is plowed in the spring, very little trouble will result.

Where corn follows corn, the stalks, if not needed for feeding purposes, should be thoroly cut up with a sharp disk or stalk cutter and turned under. Likewise, the straw should be returned to the land in some practical way, either directly or as manure. Clover should be one of the crops grown in the rotation, and it should be plowed under directly or as manure instead of being sold as hay, except when manure can be brought back.

It must be remembered, however, that in the feeding of hay, or straw, or corn stalks, a great destruction of organic matter takes place, so that even if the fresh manure were returned to the soil, there would still be a loss of 50 to 70 percent owing to the destruction of organic matter by the animal. If manure is allowed to lie in the farmyard for a few weeks or months, there is an additional loss which amounts to from one-third to two-thirds of the manure recovered from the animal. This is well shown by the results of an experiment conducted by the Maryland Experiment Station, where 80 tons of manure were allowed to lie for a year in the farmyard and at the end of that time but 27 tons remained, entailing a loss of about 66 percent of the manure. Most of this loss occurs within the first three or four months, when fermentation, or "heating," is most active. Two tons of manure were exposed from April 29 to August 29, by the

Canadian Experiment Station at Ottawa. During these four months the organic matter was reduced from 1,938 pounds to 655 pounds. To obtain the greatest value from the manure, it should be applied to the soil as soon as possible after it is produced.

It is a common practice in the corn belt to pasture the corn stalks during the winter and often rather late in the spring after the frost is out of the ground. This tramping of stock sometimes puts the soil in bad condition for working. It becomes partially puddled and will be cloddy as a result. If tramped too late in the spring, the natural agencies of freezing and thawing, and wetting and drying, with the aid of ordinary tillage, fail to produce good tilth before the crop is to be planted. Whether the crop is corn or oats, it necessarily suffers, and if the season is dry, much damage may result. If the field is put in corn, a poor stand is likely to follow, and if put in oats, a compact soil is formed which is unfavorable for their growth. Sometimes the soil is worked when too wet. This also produces a partial puddling which is unfavorable to physical, chemical, and biological processes. The bad effect will be greater if cropping has reduced the organic matter below the amount necessary to maintain good tilth.

UNIVERSITY OF ILLINOIS
Agricultural Experiment Station

SOIL REPORT NO. 10

McLEAN COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER,
E. VAN ALSTINE, and F. W. GARRETT

URBANA, ILLINOIS, MAY, 1915

INTRODUCTORY NOTE

About two-thirds of Illinois lies in the corn belt, where most of the prairie lands are black or dark brown in color. In the southern third of the state, the prairie soils are largely of a gray color. This region is better known as the wheat belt, altho wheat is often grown in the corn belt and corn is also a common crop in the wheat belt.

Moultrie county, representing the corn belt; Clay county, which is fairly representative of the wheat belt; and Hardin county, which is taken to represent the unglaciated area of the extreme southern part of the state, were selected for the first Illinois Soil Reports by counties. While these three county soil reports were sent to the Station's entire mailing list within the state, subsequent reports are sent only to those on the mailing list who are residents of the county concerned, and to any one else upon request.

Each county report is intended to be as nearly complete in itself as it is practicable to make it, and, even at the expense of some repetition, each will contain a general discussion of important fundamental principles in order to help the farmer and landowner understand the meaning of the soil fertility invoice for the lands in which he is interested. In Soil Report No. 1, "Clay County Soils," this discussion serves in part as an introduction, while in this and other reports, it will be found in the Appendix; but if necessary it should be read and studied in advance of the report proper.

McLEAN COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER, E. VAN ALSTINE, and F. W. GARRETT

McLean county is located in the central part of Illinois in the early Wisconsin glaciation. The general topography is undulating to slightly rolling, tho an area in the northwestern part of the county along the Mackinaw river is in part badly broken.

The difference in topography is due to two causes—glacial action and stream erosion. This county was covered by two ice sheets during the Glacial period. At that time snow and ice accumulated in the region of Labrador and to the west of Hudson Bay to such an amount that it pushed southward until a point was reached where the ice melted as rapidly as it advanced. In moving across the country, the ice gathered up all sorts and sizes of material, including clay, silt, sand, gravel, boulders, and even large masses of rock. Many of these were carried for hundreds of miles and rubbed against the surface rocks or against each other until ground into powder. When the limit of advance was reached by the melting of the ice, this material accumulated in a broad undulating ridge, or moraine. When the ice melted away more rapidly than the glacier advanced, the terminus of the glacier would recede and leave this material deposited somewhat uniformly over the tract, marking the area previously covered by the ice sheet. Other advances occurred which built up other moraines. The intervening intermorainal tracts are occupied chiefly by level, undulating, or slightly rolling plains.

The material transported by the glacier varied with the character of the rocks over which it passed. Granites, limestones, sandstones, shales, et cetera, were mixed and ground up together. This mixture of all kinds of material—boulders, clay, silt, sand, and gravel—is called boulder clay, till, glacial drift, or simply drift. The grinding and denuding power of glaciers is enormous. A mass of ice 100 feet thick exerts a pressure of 40 pounds per square inch, and this ice sheet may have been thousands of feet in thickness. The materials carried along in this mass of ice, especially the boulders and pebbles, became powerful agents for grinding and wearing away the surface over which the ice passed. Preglacial ridges and hills were rubbed down, valleys were filled with the debris, and the surface features were changed entirely.

McLean county was first covered by the Illinois glacier, which did its share toward leveling the region and covering it with a deposit of boulder clay. After this a long period elapsed, during which a soil known as the Sangamon soil was formed from this glacial deposit. Then another advance occurred, known as the Iowan glacier. This glacier did not reach McLean county, but after its melting the state was covered with a deposit of wind-blown loess, which buried the old soil that was formed from the Illinois glacial drift. A new soil was formed from the loess, and after a long period had elapsed another ice advance occurred—the early Wisconsin glacier. This covered the entire county, bringing

with it immense quantities of the material which now covers the county to an average depth of 200 feet and in many places reaches a depth of 250 feet. The outer limit of this glaciation, known as the Shelbyville moraine, extends to the south-western corner of McLean county. (See the state soil map in Bulletin 123.)

The early Wisconsin glacier advanced and receded in this county at least three different times, building up terminal moraines with each advance. The largest of these is the Bloomington moraine, which in the western two-thirds of the county is made up of a double ridge, coalescing as it reaches the eastern part. This double ridge indicates two distinct glacial advances. Another moraine, known as the Cropsey ridge, occurs in the northeastern part of the county. A small spur from the Champaign moraine extends into the southeastern corner of the county, and it is likely that the extension of this was covered by the Bloomington moraine, which is about 100 feet higher than the area to the south. The intermorainal tracts are naturally poorly drained. They were formerly occupied by swamps, which have required much artificial drainage.

PHYSIOGRAPHY

The altitude of McLean county varies from 600 to about 900 feet above sea level, with an average of approximately 750 feet. The highest point, 920 feet, is on the Bloomington moraine near the center of Township 23 North, Range 4 East. The altitude of some of the points are as follows: Arrowsmith, 877 feet; Bellflower, 784; Bloomington, 821; Chenoa, 723; Colfax, 742; Cropsey, 802; Danvers, 808; Downs, 794; Ellsworth, 863; Funk's Grove, 694; Gillum, 820; Gridley, 752; Hudson, 768; Lexington, 746; Leroy, 780; McLean, 708; Normal, 790; Saybrook, 786; Weedman, 725.

The county is divided into four drainage areas: the Mackinaw in the north and northwest, the Sangamon in the east, Rooks creek, a branch of the Vermilion, in the northeast, and Sugar creek and its branches in the south and southwest. All these streams, however, flow into the Illinois river. Drainage is naturally well developed in the western half of the county.

SOIL MATERIAL AND SOIL TYPES

The early Wisconsin glacier left extensive deposits of boulder clay over the county, but the soils as a general rule are not formed from this material. After the Wisconsin glacier, the county was again covered by a deposit of fine wind-blown material, loessial in character, varying from 2 to 7 feet in depth, and it is from this loess that the soil has generally been formed. In very small areas on some of the more rolling parts, this fine material has been removed to such an extent that the exposed boulder clay may constitute the soil material.

The soils of the county are divided into four classes, as follows:

(a) Upland prairie soils, rich in organic matter. These were originally covered with wild prairie grasses, the partially decayed roots of which have been the source of the organic matter. The flat prairie land contains the higher amount of this constituent because the grasses and roots grew more luxuriantly there, and the higher moisture content preserved them from complete decay.

(b) Upland timber soils, including those zones along stream courses over which for a long period of time forests once extended. These soils contain much

TABLE 1.—SOIL TYPES OF McLEAN COUNTY

Soil type No.	Name of type	Area in square miles	Area in acres	Percent of total area
	(a) Upland Prairie Soils (page 24)			
926 } 1126 }	Brown silt loam	847.38	542 323.2	72.602
1120	Black clay loam	168.69	107 961.6	14.474
1120.2	Gravelly black clay loam	4.04	2 585.6	.345
1128	Brown-gray silt loam on tight clay	2.42	1 548.8	.207
990 } 1190 }	Gravelly loam	.15	96.0	.012
	(b) Upland Timber Soils (page 29)			
934 } 1134 }	Yellow-gray silt loam	73.42	46 988.8	6.227
935 } 1135 }	Yellow silt loam	27.43	17 555.2	2.357
	(c) Terrace Soils (page 37)			
1527	Brown silt loam over gravel	.26	166.4	.002
1526.2	Brown silt loam on gravel	1.77	1 132.8	.152
1534.2	Yellow-gray silt loam on gravel	.97	620.8	.083
	(d) Swamp and Bottom-Land Soils (page 38)			
1401	Deep peat	.13	83.2	.011
1426	Deep brown silt loam	23.88	15 283.2	2.008
1454	Mixed loam	18.06	11 558.4	1.520
	Total	1 168.60	747 904.0	100.000

less organic matter, because the large roots of dead trees and the surface accumulations of leaves, twigs, and fallen trees were burned by forest fires or suffered almost complete decay. The timber lands are divided chiefly into two classes—the undulating and the hilly areas.

(c) Terrace soils. These have been formed by deposits from flooded streams overloaded with coarse sediment at the time of the melting of the glacier. Finer deposits which were later made upon the coarse gravelly material now constitute the soil.

(d) Swamp and bottom lands, which include the flood plains along streams and some small peaty swamp areas.

Table 1 gives the area of each type of soil in the county and its percentage of the total area. It will be observed that 72½ percent of the area consists of brown silt loam, 14½ percent of black clay loam, and 6 percent of yellow-gray silt loam, these three types covering 93 percent of the county. The accompanying maps show the location and boundary lines of every type of soil in the county, even down to areas of a few acres.

THE INVOICE AND INCREASE OF FERTILITY IN McLEAN COUNTY SOILS

SOIL ANALYSIS

In order to avoid confusion in applying in a practical way the technical information contained in this report, the results are given in the most simplified form. The composition reported for a given soil type is, as a rule, the average of many analyses, which, like most things in nature, show more or less variation; but for all practical purposes the average is most trustworthy and sufficient.

(See Bulletin 123, which reports the general soil survey of the state, together with many hundred individual analyses of soil samples representing twenty-five of the most important and most extensive soil types in the state.)

The chemical analysis of a soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but, as explained in the Appendix, the rate of liberation is governed by many factors. Also, as there stated, probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that the productive power of normal soil in humid sections depends upon the stock of plant food contained in the soil and upon the rate at which it is liberated.

The fact may be repeated, too, that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all plants, only one (hydrogen) from water, while seven are secured from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes) in case the amount liberated from the soil is insufficient. But even the leguminous plants (which include the clovers, peas, beans, alfalfa, and vetches), in common with other agricultural plants, secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron, and sulfur) and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Table A in the Appendix shows the requirements of large crops for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally from natural sources in sufficient abundance, compared with the amounts needed by plants, so that they are never known to limit the yield of common farm crops.)

In Table 2 are reported the amounts of organic carbon (the best measure of the organic matter) and the total amounts of the five important elements of plant food contained in 2 million pounds of the surface soil of each type,—the plowed soil of an acre about 6⅔ inches deep. In addition, the table shows the amount of limestone present, if any, or the soil acidity as measured by the amount of limestone required to neutralize the acidity existing in the soil.

The soil to the depth indicated includes at least as much as is ordinarily turned with the plow, and represents that part with which the farm manure, limestone, phosphate, or other fertilizer applied in soil improvement is incorporated. It is the soil stratum that must be depended upon in large part to furnish the necessary plant food for the production of crops, as will be seen from the information given in the Appendix. Even a rich subsoil has little or no value if it lies beneath a worn-out surface, for the weak, shallow-rooted plants will be unable to reach the supply of plant food in the subsoil. If, however, the fertility of the surface soil is maintained at a high point, then the plants,

SOIL SURVEY MAP OF McLEAN COUNTY
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LEGEND

(a) UPLAND PRAIRIE SOILS

- 26 / 926 / 1126 — Brown silt loam
- 264 / 9264 / 11264 — Brown silt loam on gravel
- 20 / 1120 — Black clay loam
- 20.2 / 1120.2 — Gravelly black clay loam
- 28 / 1128 — Brown-gray silt loam on tight clay
- 90 / 990 / 1190 — Gravelly loam

(b) UPLAND TIMBER SOILS

- 34 / 934 / 1134 — Yellow-gray silt loam
- 35 / 935 / 1135 — Yellow silt loam

(c) TERRACE SOILS

- 27 / 1527 — Brown silt loam over gravel
- 264 / 1526.4 — Brown silt loam on gravel
- 344 / 1534.4 — Yellow-gray silt loam on gravel

(d) SWAMP AND BOTTOM-LAND SOILS

- 1426 — Deep brown silt loam
- 54 / 1454 — Mixed loam
- 1401 — Deep peat

900 Early Wisconsin Moraines

1100 Early Wisconsin Intermorainal Areas

Scale
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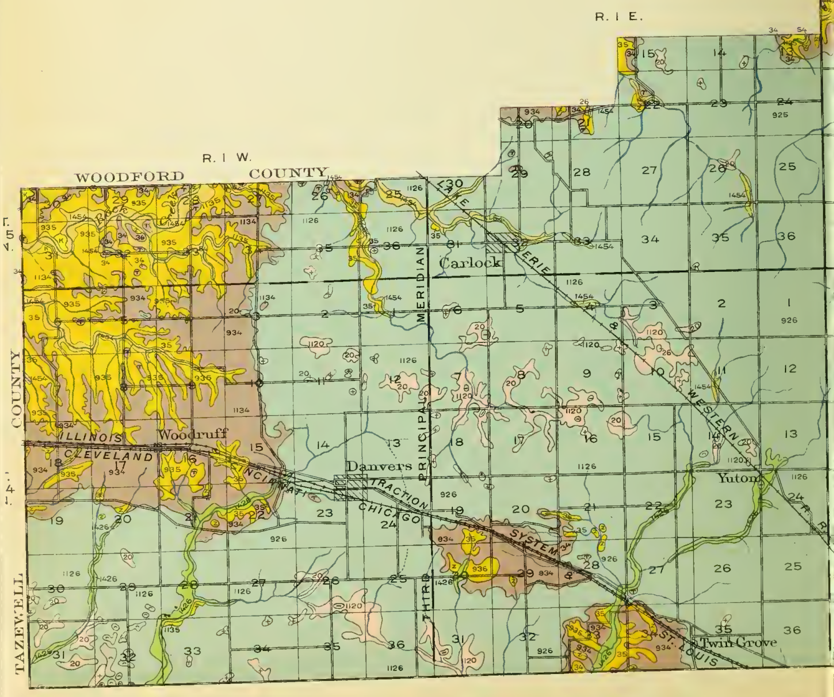

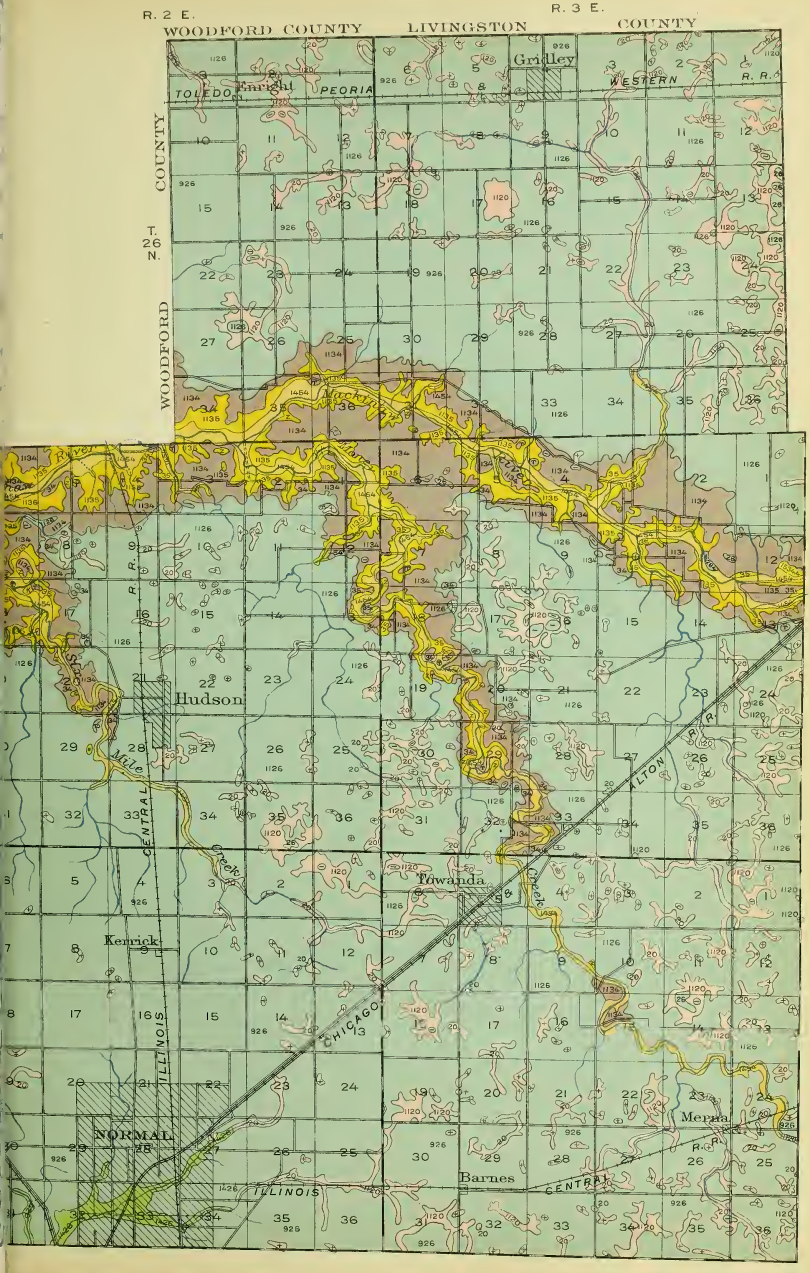

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with a vigorous start from the rich surface soil, can draw upon the subsurface and subsoil for a greater supply of plant food.

By easy computation it will be found that the most common prairie soil of McLean county does not contain more than enough total nitrogen in the plowed soil for the production of maximum crops for forty years, while the upland timber soils contain, as an average, much less nitrogen than the prairie land.

With respect to phosphorus, the condition differs only in degree, more than eight-tenths of the soil area of the county containing no more of that element than would be required for fifteen crop rotations if such yields were secured as are suggested in Table A of the Appendix. It will be seen from the same table that with the cereals about three-fourths of the phosphorus taken from the soil is deposited in the grain, while only one-fourth remains in the straw or stalks.

On the other hand, the potassium is sufficient for 28 centuries if only the grain is sold, or for 450 years even if the total crops should be removed and nothing returned. The corresponding figures are about 2,000 and 500 years for magnesium, and about 9,000 and 200 years for calcium. Thus, when measured by the actual crop requirements for plant food, potassium is no more limited than magnesium and calcium; and as explained in the Appendix, with magnesium, and more especially with calcium, we must also consider the fact that loss by leaching is far greater than by cropping.

These general statements relating to the total quantities of plant food in the plowed soil certainly emphasize the fact that the supplies of some of these necessary elements of fertility are extremely limited when measured by the needs of large crop yields for even one or two generations of people, and, with a population increasing by more than 20 percent each decade, the future needs of the

TABLE 2.—FERTILITY IN THE SOILS OF McLEAN COUNTY, ILLINOIS

Average pounds per acre in 2 million pounds of surface soil (about 0 to 6⅔ inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity
	Upland Prairie Soils								
1126	Brown silt loam........	57 410	4 870	1 120	36 640	8 350	9 560		60
1120	Black clay loam........	91 370	8 160	2 000	34 210	16 580	31 240	Often	Rarely
1120.2	Gravelly black clay loam.	65 180	6 020	1 620	32 520	23 920	74 740	170 760	
1128	Brown-gray silt loam on tight clay	47 880	4 200	1 380	36 220	6 780	7 300		120
1190	Gravelly loam	32 520	3 040	1 000	35 240	8 240	6 780		20
	Upland Timber Soils								
1134	Yellow-gray silt loam..	33 670	2 940	1 050	35 910	6 220	7 820		60
1135	Yellow silt loam.......	17 780	1 650	750	35 440	7 330	6 420		150
	Terrace Soils								
1527	Brown silt loam over gravel	65 180	5 980	1 420	36 180	8 700	7 140		40
1526.2	Brown silt loam on gravel	41 930	3 770	1 080	38 430	8 050	7 480		40
1534.4	Yellow-gray silt loam on gravel	35 520	3 660	1 080	37 000	6 700	7 880		20
	Swamp and Bottom-Land Soils								
1401	Deep peat	318 850	29 530	2 710	6 240	5 610	33 460	3 930	
1426	Deep brown silt loam...	79 940	6 620	2 120	38 980	11 260	16 500		60
1454	Mixed loam	65 760	5 980	1 760	42 620	14 080	20 100	8 120	

people dependent upon the corn belt are likely to be far greater than the requirements of the past, and soil fertility and crop yields should not decrease but increase.

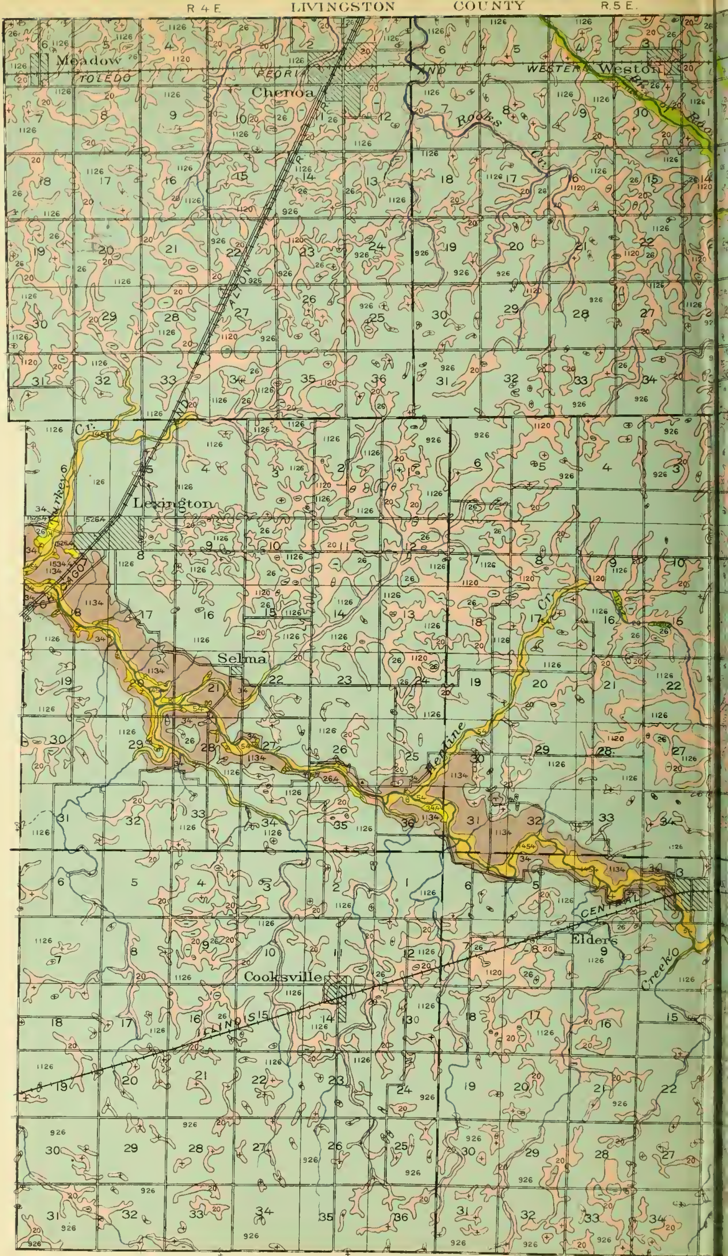
In the production of general farm crops, McLean is now the leading county in the United States. The only rival counties for the position of greatest in agriculture are Los Angeles, Cal., and Lancaster, Pa. The crop values reported for these counties by the latest United States census (for 1909) are as follows:

County	Value of all crops	Value of all crops except tobacco, vegetables, fruits, and nuts
Los Angeles, California	$14 720 884	$6 734 259
Lancaster, Pennsylvania	13 059 588	8 617 170
McLean, Illinois	12 811 506	12 690 404

McLean county produced 16 million bushels of corn in 1909, while 8 million were produced in the six New England states, less than 10 million in the eleven Western states, 18 million in Maryland, 21 million in South Carolina, 39 million in Georgia, and 390 million in Illinois. And yet McLean county produced but little more than half a crop, measured by its normal climatic possibilities under rational systems of soil improvement. The ten-year average yield of corn for McLean county is 39 bushels per acre, according to the Statistical Reports of the Illinois State Board of Agriculture for the years 1905 to 1914. During the same ten years the average acre-yield was 78.3 bushels on the University of Illinois North Farm at Urbana, where organic manures, limestone, and phosphorus had been applied. (See records of Plots 6 and 7, Tables 3 and 4, pages 10 and 11.) Such results should induce careful study of the individual farm with its particular soil type or types, in order that the best methods may be adopted for soil improvement and preservation.

The variation among the different types of soil in McLean county with respect to their content of important plant-food elements is very marked. Thus the richest prairie land (black clay loam) contains from three to five times as much nitrogen and twice as much phosphorus as the common upland timber soils; and the deep peat soil contains eighteen times as much nitrogen but only one-sixth as much potassium as the yellow silt loam. The most significant facts revealed by the investigation of the McLean county soils are the lack of limestone and the low phosphorus content of the common prairie soil and of the most extensive timber type, which combined cover nearly 80 percent of the entire county. And yet both of these deficiencies can be overcome at relatively small expense by the application of ground limestone and fine-ground raw rock phosphate; and, after these are provided, clover can be grown with more certainty and in greater abundance, and nitrogen can thus be secured from the inexhaustible supply in the air. If the clover is then returned to the soil, either directly or in farm manure, the combined effect of limestone, phosphorus, and nitrogenous organic matter, with a good rotation of crops, will in time double the yield of corn and other crops on most farms.

Fortunately, some definite field experiments have already been conducted on brown silt loam, the most extensive type of soil in the early Wisconsin glaciation, as at Urbana in Champaign county, at Sibley in Ford county, and at Bloomington



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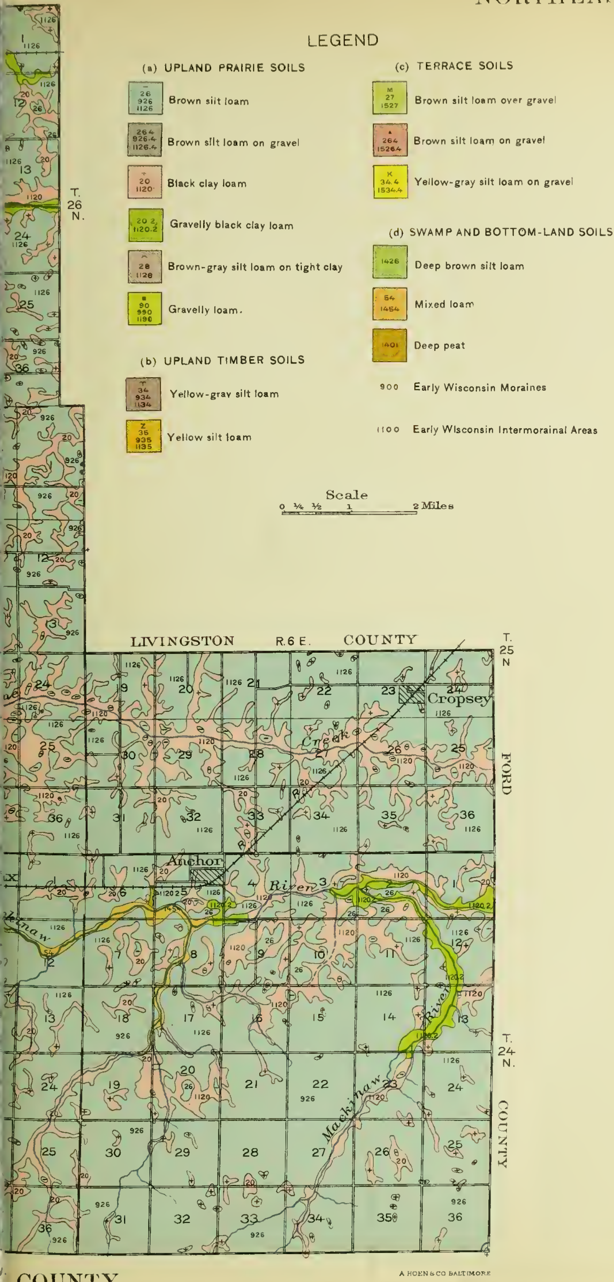


COUNTY

PERIMENT STATION

in McLean county. Before considering in detail the individual soil types, it seems advisable to study some of the results already obtained where definite systems of soil improvement have been tried out on some of these experiment fields in different parts of central Illinois.

Results of Field Experiments at Urbana

A three-year rotation of corn, oats, and clover was begun on the North Farm at the University of Illinois in 1902, on three fields of typical brown silt loam prairie land which, after twenty years or more of pasturing, had grown corn in 1895, 1896, and 1897 (when careful records were kept of the yields produced), and had then been cropped with clover and grass on one field (Series 100), oats on another (Series 200), and oats, cowpeas, and corn on the third field (Series 300) until 1901.

From 1902 to 1910 the three-year rotation (with cowpeas in place of clover in 1902) was followed; the average yields are recorded in Table 3. A small crop of cowpeas in 1902 and a partial crop of clover in 1904 constituted all the hay harvested during the first rotation, mammoth clover grown in 1903 having lodged so that it was plowed under. (The yields were taken by carefully weighing the clover from small representative areas, but while the differences were thus ascertained and properly credited temporarily to the different soil treatments, they must ultimately reappear in subsequent crop yields, and consequently the 1903 clover crop is omitted from Table 3 in computing yields and values.) The average yields given represent one-third of the two small crops.

From 1902 to 1907 legume cover crops (Le), such as cowpeas and clover, were seeded in the corn at the last cultivation on Plots 2, 4, 6, and 8, but the growth was small and the effect, if any, was to decrease the returns from the regular crops. Since 1907 crop residues (R) have been returned to those plots. These consist of the stalks of corn, the straw of small grains, and all legumes except alfalfa hay and the seed of clover and soybeans.

On Plots 3, 5, 7, and 9, manure (M) was applied for corn at the rate of 6 tons per acre during the second rotation, and subsequently as many tons of manure have been applied as there were tons of air-dry produce harvested from the corresponding plots.

Lime (L) was applied on Plots 4 to 10 at the rate per acre of 250 pounds of air-slaked lime in 1902 and 600 pounds of limestone in 1903. Subsequently 2 tons per acre of limestone was applied to these plots on Series 100 in 1911, on Series 200 in 1912, on Series 300 in 1913, and on Series 400 in 1914; also 2½ tons per acre on Series 500 in 1911, two more fields having been brought into rotation, as explained on page 8.

Phosphorus (P) has been applied on Plots 6 to 9 at the rate of 25 pounds per acre per annum in 200 pounds of steamed bone meal; but beginning with 1908, one half of each phosphorus plot has received 600 pounds of rock phosphate in place of the 200 pounds of bone meal, the usual practice being to apply and plow under at one time all phosphorus and potassium required for the rotation.

Potassium (K=kalium) has been applied on Plots 8 and 9 at the yearly rate of 42 pounds per acre in 100 pounds of potassium sulfate, regularly in connection with the bone meal and rock phosphate.

On Plot 10 about five times as much manure and phosphorus are applied as on the other plots, but this "extra heavy" treatment was not begun until

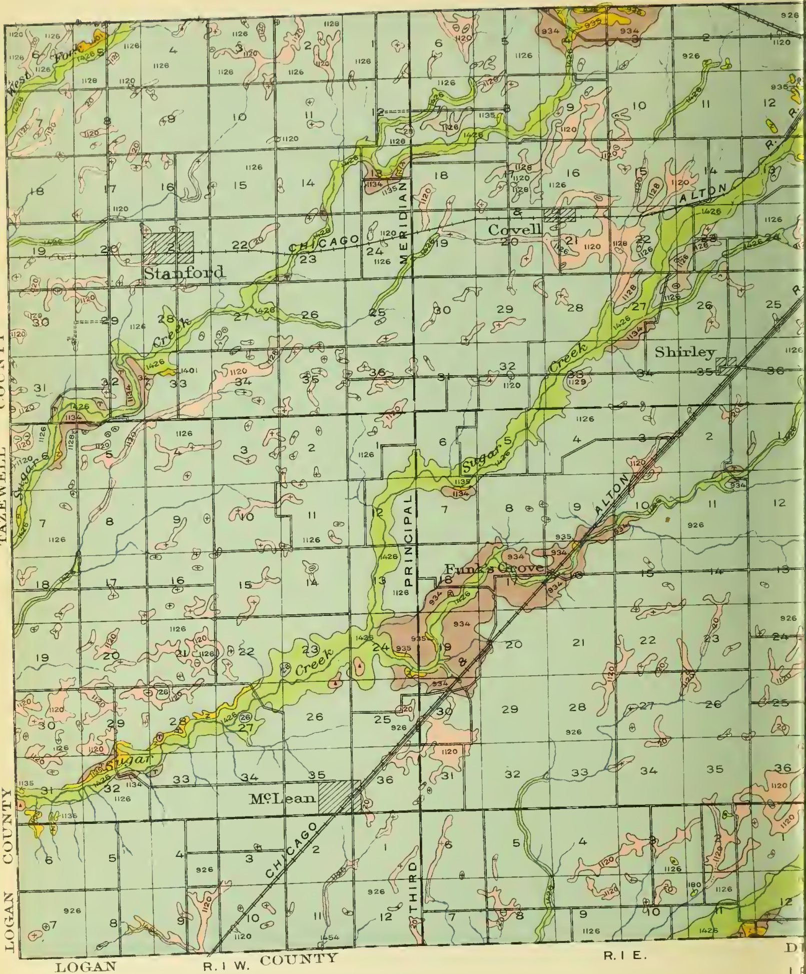
1906, only the usual lime, phosphorus, and potassium having been applied in previous years. The purpose in making these heavy applications is to try to determine the climatic possibilities in crop yields by removing the limitations of inadequate fertility.

Series 400 and 500 were cropped in corn and oats from 1902 to 1910, but the corresponding plots were treated the same as in the three-year rotation. Beginning with 1911, the five series have been used for a combination rotation, wheat, corn, oats, and clover being rotated for five years on four fields, while alfalfa occupies the fifth field, which is then to be brought under the four-crop system to make place for alfalfa on one of the other fields for another five-year period, and so on. (See Table 4.)

From 1911 to 1914 soybeans were substituted three years because of clover failure; accordingly three-fourths of the soybeans and one-fourth of the clover are used to compute values. Alfalfa from the 1911 seeding so nearly failed that after cutting one crop in 1912 the field was plowed and reseeded. The average yield reported for alfalfa in Table 4 is one-fourth of the combined crops of 1912, 1913, and 1914.

The "higher prices" allowed for produce are $1 a bushel for wheat and soybeans, 50 cents for corn, 40 cents for oats, $10 for clover seed, and $10 a ton for hay; while the "lower prices" are 70 percent of these values, or 70 cents

PLATE 1.—CLOVER IN 1913 ON URBANA FIELD
FARM MANURE APPLIED
YIELD, 1.43 TONS PER ACRE



(a) UPLAND PRAIRIE SOILS

26 926 1126	Brown silt loam
264 926.4 1126.4	Brown silt loam on gravel
20 1120	Black clay loam
20.2 1120.2	Gravelly black clay loam
28 1128	Brown-gray silt loam on tight clay
90 990 1190	Gravelly loam

(b) UPLAND TIMBER SOILS

34 934 1134	Yellow-gray silt loam
35 935 1135	Yellow silt loam

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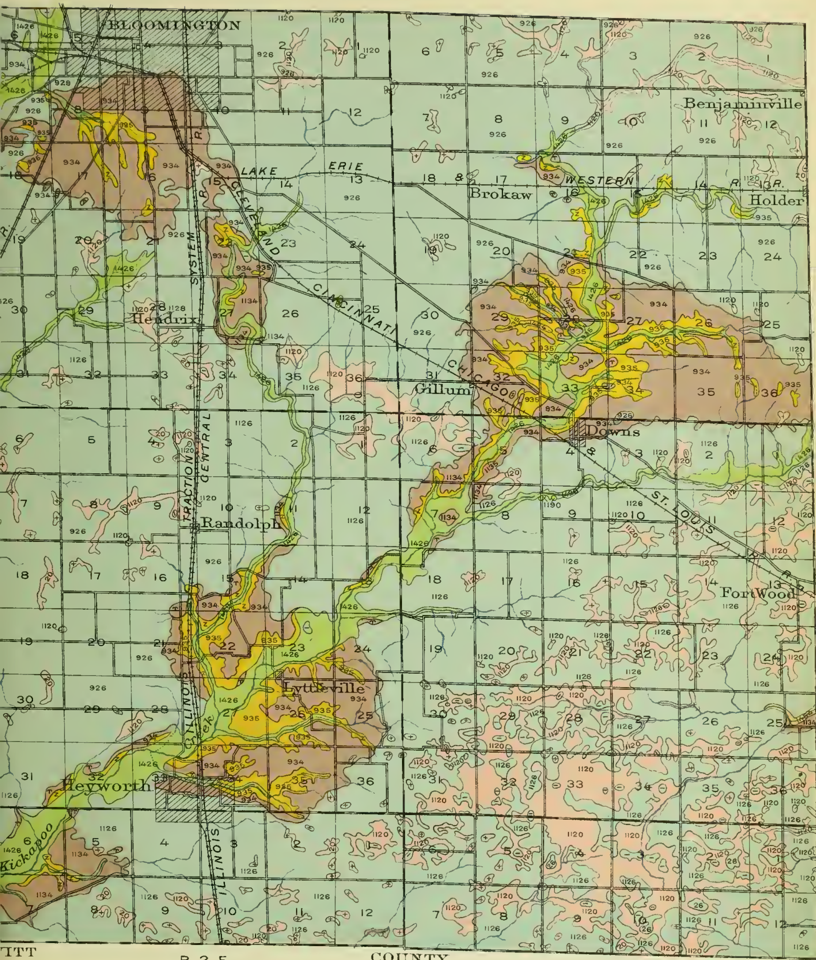

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(c) TERRACE SOILS

M 27 1527	Brown silt loam over gravel
▲ 264 15264	Brown silt loam on gravel
K 34.4 15344	Yellow-gray silt loam on gravel

(d) SWAMP AND BOTTOM-LAND SOILS

1426	Deep brown silt loam
54 1454	Mixed loam
1401	Deep peat

900 Early Wisconsin Moraines

1100 Early Wisconsin Intermorainal Areas

Scale

0 ¼ ½ 1 2 Miles

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OF McLEAN COUNTY

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for wheat and soybeans, 35 cents for corn, 28 cents for oats, $7 for clover seed, and $7 a ton for hay. The double set of values is used to emphasize the fact that a given practice may or may not be profitable, depending upon the prices of farm produce. The lower prices are conservative, and unless otherwise stated, they are the values regularly used in the discussion of results. It should be understood that the increase produced by manures and fertilizers requires increased expense for binding twine, shocking, stacking, baling, threshing, hauling, storing, and marketing. Measured by the average Illinois prices for the past ten years, these lower values are high enough for farm crops standing in the field ready for the harvest.

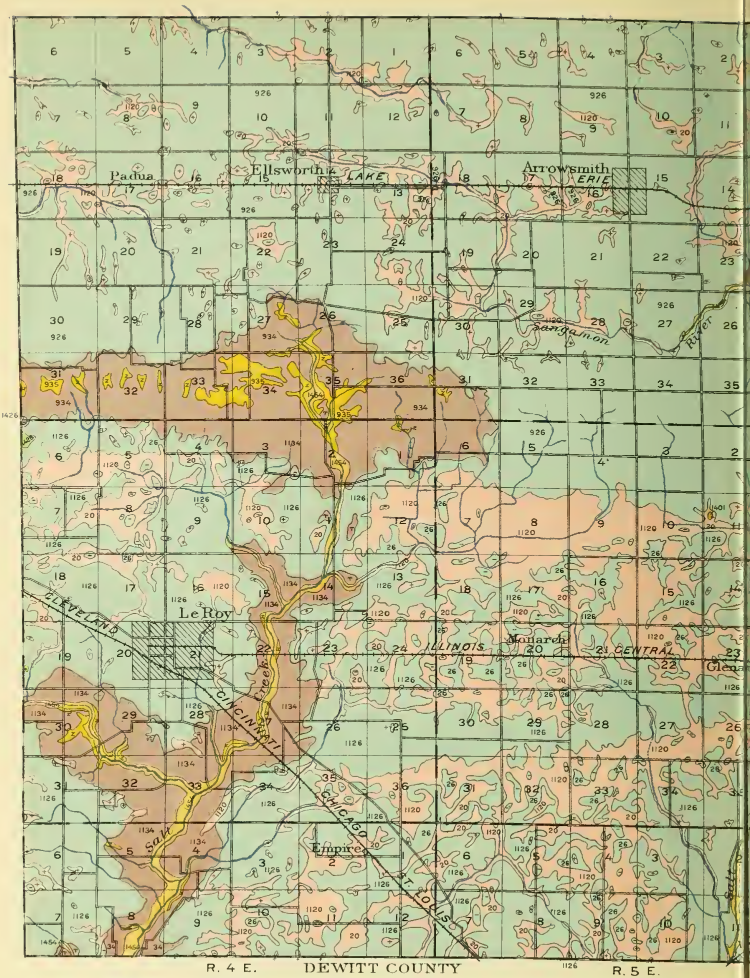
The cost of limestone delivered at the farmers' railroad station in carload lots averages about $1.25 per ton. Steamed bone meal in carloads costs from $25 to $30 per ton. Fine-ground raw rock phosphate containing from 260 to 280 pounds of phosphorus, or as much as the bone meal contains, ton for ton, but in less readily available form, usually costs the farmer from $6.50 to $7.50 per ton in carloads. (Acid phosphate carrying half as much phosphorus, but in soluble form, commonly costs from $15 to $17 per ton delivered in carload lots in central Illinois.) Under normal conditions potassium costs about 6 cents a pound, or $2.50 per acre per annum for the amount applied in these experiments, the same as the cost of 200 pounds of steamed bone meal at $25 per ton.

PLATE 2.—CLOVER IN 1913 ON URBANA FIELD
FARM MANURE, LIMESTONE, AND PHOSPHORUS APPLIED
YIELD, 2.90 TONS PER ACRE

TABLE 3.—YIELDS PER ACRE, THREE-YEAR AVERAGES: URBANA FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Serial plot No.	First rotation, 1902-1904						Second rotation, 1905-1907						Third rotation, 1908-1910					
	Soil treatment	Corn, bu.	Oats, bu.	Hay, tons	Value of 3 crops		Soil treatment	Corn, bu.	Oats, bu.	Clover, tons	Value of 3 crops		Soil treatment	Corn, bu.	Oats, bu.	Clover, tons (bu.)	Value of 3 crops	
					Lower prices	Higher prices					Lower prices	Higher prices					Lower prices	Higher prices
1	0........	75.4	48.8	.49	$43.48	$62.12	0......	71.5	46.6	2.07	$52.56	$75.09	0......	49.4	40.8	2.30	$44.81	$64.02
2	Le......	77.4	45.1	.44	42.80	61.14	Le.....	68.5	52.0	1.83	51.34	73.35	R......	51.5	43.4	(1.93)	43.69	62.41
3	0........	75.3	50.4	.41	43.33	61.91	M.....	80.5	54.8	2.19	58.84	84.07	M.....	69.3	46.2	2.53	54.90	78.43
4	LeL.....	78.4	47.3	.42	43.62	62.32	LeL....	72.3	58.6	1.98	55.57	79.39	RL....	58.1	45.7	(2.02)	47.27	67.53
5	L.......	80.8	58.2	.44	47.66	68.08	ML....	84.8	59.8	2.46	63.64	90.92	ML....	74.9	47.5	2.94	60.09	85.85
6	LeLP....	88.0	52.5	.50	49.00	70.00	LeLP..	90.4	70.7	2.69	70.26	100.38	RLP...	83.8	54.5	(2.64)	63.07	90.10
7	LP......	88.8	56.6	.98	53.79	76.84	MLP...	93.2	71.6	3.47	76.96	109.94	MLP...	86.6	55.4	4.17	75.01	107.16
8	LeLPK..	90.1	48.3	.64	49.53	70.77	LeLPK	93.8	71.7	3.06	74.32	106.18	RLPK	86.7	53.5	(1.99)	59.26	84.65
9	LPK....	90.5	54.3	1.34	56.26	80.37	MLPK	95.6	66.9	3.73	78.30	111.86	MLPK	90.9	53.6	3.90	74.12	105.89
10	LPK....	86.5	53.2	1.23	53.78	76.83	MxLPx	90.1	62.9	2.86	69.17	98.81	MxLPx	81.3	54.3	3.79	70.19	100.27

Le=legume cover crop; L=lime; P=phosphorus; K=potassium; M=manure; x=extra heavy applications of manure and phosphorus; R=crop residues (corn stalks, straw of wheat and oats, and all legumes except seed).



LEGEND

(a) UPLAND PRAIRIE SOILS

26 926 1126	Brown silt loam
264 9264 11264	Brown silt loam on gravel
20 1120	Black clay loam
20 2 1120 2	Gravelly black clay loam
28 1128	Brown-gray silt loam on tight clay
90 990 1190	Gravelly loam

(b) UPLAND TIMBER SOILS

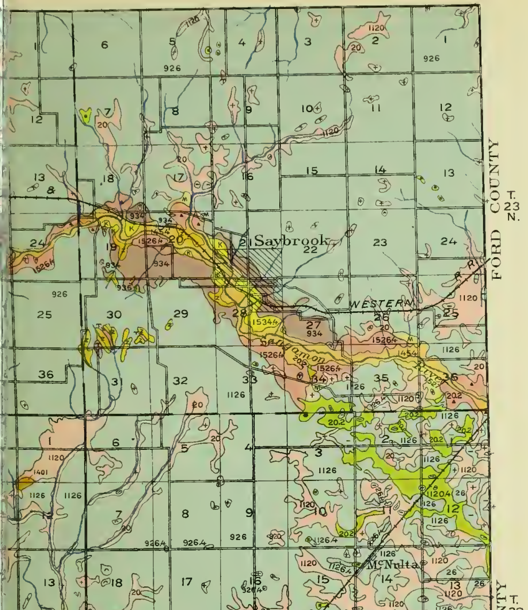
34 934 1134	Yellow-gray silt loam
35 935 1135	Yellow silt loam

(c) TERRACE SO

27 1527	Brown silt loan
264 1526.4	Brown silt loan
34.4 1534.4	Yellow-gray silt

SOIL SURVEY MAP OF McL

UNIVERSITY OF ILLINOIS AGRICULTURAI



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(d) SWAMP AND BOTTOM-LAND SOILS

…ver gravel

1426 Deep brown silt loam

900 Early Wisconsin Moraines

…n gravel

54 / 1454 Mixed loam

1100 Early Wisconsin Intermorainal Areas

…oam on gravel

1401 Deep peat

Scale

0 ¼ ½ 1 2 Miles

…AN COUNTY

…EXPERIMENT STATION

A. HOEN & CO. BALTIMORE

Table 4.—Yields per Acre, Four-year Averages, 1911-19[illegible] Urbana Field
Brown Silt Loam Prairie; Early Wisconsin Gl[illegible]ation

Serial plot No.	Soil treatment	Wheat, bu.	Corn, bu.	Oats, bu.	Soybeans–3, tons (bu.)	Clover–1, tons (bu.)	Alfalfa, tons	Value of 5 crops Lower prices	Higher prices
1	0........	18.3	50.8	39.8	1.60	1.70	1.70	$65.0[illegible]	[illegible]
2	R.......	19.7	53.8	40.6	(20.1)	(.74)	1.27	64[illegible]	[illegible]
3	M.......	20.3	59.3	48.8	1.60	1.43	[illegible]	[illegible]	[illegible]
4	RL......	22.3	55.7	42.8	(19.0)	(1.03)	[illegible]	[illegible]	[illegible]
5	ML.....	24.9	58.6	51.6	1.66	1.94	[illegible]	[illegible]	[illegible]
6	RLP....	37.4	62.2	58.7	(21.0)	(2.48)	[illegible]	[illegible]	[illegible]
7	MLP....	36.6	63.8	60.9	1.88	2.90	[illegible]	[illegible]	[illegible]
8	RLPK...	36.1	58.9	59.1	(22.2)	(1.41)	[illegible]	[illegible]	[illegible]
9	MLPK..	35.3	59.6	65.1	2.09	2.72	[illegible]	[illegible]	[illegible]
10	MxLPx..	43.5	55.7	67.2	2.14	2.94	[illegible]	[illegible]	[illegible]

To these cash investments must be added the expense o[illegible] ing the materials. This will vary with the distance from [illegible] road station, with the character of roads, and with the farm[illegible] diate requirements of other lines of farm work. It is the pa[illegible] such materials in advance to be shipped when specified, so [illegible] ceived and applied when other farm work is not too press[illegible] when the roads are likely to be in good condition.

The practice of seeding legume cover crops in the cornfield at the last cultivation where oats are to follow the next year has not been found profitable, as a rule, on good corn-belt soil; but the returning of the crop residues to the land may maintain the nitrogen and organic matter equally as well as the hauling and spreading of farm manure,—and this makes possible permanent systems of farming on grain farms as well as on live-stock farms, provided, of course, that other essentials are supplied. (Clover with oats or wheat, as a cover crop to be plowed under for corn, often gives good results.)

At the lower prices for produce, manure (6 tons per acre) was worth $1.05 a ton as an average for the first three years it was applied (1905 to 1907). The next rotation the average application of 10.21 tons per acre on Plot 3 was worth $10.09, or 99 cents a ton. The last four years, 1911 to 1914, the average amount applied (once for the rotation) on Plot 3 was 11.35 tons per acre, worth $6.42, or 57 cents a ton, as measured by its effect on the wheat, corn, oats, soybeans, and clover. Thus, as an average of the ten years' results, the farm manure applied to Plot 3 has been worth 84 cents a ton on common corn-belt prairie soil, with a good crop rotation including legumes. During the last rotation period moisture has been the limiting factor to such an extent as probably to lessen the effect of the manure.

Aside from the crop residues and manure, each addition affords a duplicate test as to its effect. Thus the effect of limestone is ascertained by comparing Plots 4 and 5, not with Plot 1, but with Plots 2 and 3; and the effect of phosphorus is ascertained by comparing Plots 6 and 7 with Plots 4 and 5, respectively.

As a general average, the plots receiving limestone have produced $1.22 an acre a year more than those without limestone, and this corresponds to more than $6 a ton for all of the limestone applied; but the amounts used before 1911 were so small and the results vary so greatly with the different plots, crops, and seasons that final conclusions cannot be drawn until further data are secured,

the first 2-ton applications having been completed only for 1914. However, all comparisons by rotation periods show some increase for limestone, varying from 82 cents on three acres (Plot 4) during the first rotation, to $8.75 on five acres (Plot 5) as an average of the last four years; and the need of limestone for best [illegible] and highest profits seems well established.

[illegible] average of duplicate trials (Plots 6 and 7), phosphorus in bone meal [illegible] valued at $1.92 per acre per annum for the first three years [illegible] next three; and the corresponding subsequent average in- [illegible] l and raw phosphate (one-half plot of each) were $5.12 for [illegible] d $5.36 for the last four years, 1911 to 1914. The annual [illegible] phosphorus is $2.80 in bone meal at $28 a ton, or $2.10 for [illegible] a ton.

[illegible] ied at an estimated cost of $2.50 an acre a year, seemed to [illegible] ases, as an average, during the first and second rotations; [illegible] se increases have been slightly more than lost in reduced [illegible] net result to date being an average loss of $2.53 per acre [illegible] g the cost of the potassium.

[illegible] as nearly paid its cost during the first rotation, and has subsequently pa[illegible] annual cost and about 100 percent net profit; while potassium, as a general average, has produced no effect, and money spent for its applica-

PLATE 3.—CLOVER ON URBANA FIELD, SOUTH FARM
CROP RESIDUES PLOWED UNDER

tion has been lost. These field results are in harmony with what might well be expected on land naturally containing in the plowed soil of an acre only about 1,200 pounds of phosphorus and more than 36,000 pounds of potassium.

The total value of five average crops harvested from the untreated land during the last four years is $65. Where limestone and phosphorus have been used together with organic manures (either crop residues or farm manure), the corresponding value exceeds $98. Thus 200 acres of the properly treated land would produce as much in crops and in value as 300 acres of the untreated land.

The excessive applications on Plot 10 have usually produced rank growth of straw and stalk, with the result that oats have often lodged badly and corn has frequently suffered from drouth and eared poorly. Wheat, however, has as an average yielded best on this plot. The largest yield of corn on Plot 10 was 118 bushels per acre in 1907.

As an average of the results secured during the twelve years 1903 to 1914, on the University South Farm where fine-ground raw rock phosphate is applied at the rate of 500 pounds per acre per annum on the typical brown silt loam prairie soil, the return for each ton of phosphate[1] used has been $13.57 on Series

PLATE 4.—CLOVER ON URBANA FIELD, SOUTH FARM
FINE-GROUND ROCK PHOSPHATE PLOWED UNDER WITH CROP

[1]During the first four years, Series 100 received only 1,500 pounds per acre of phosphate, and both series received also ½ ton per acre of limestone, the effect of which probably would be slight, as may be judged from the data secured later and reported herein.

100 and $12.07 on Series 200, with the "lower prices" allowed for produce, the rotation being wheat, corn, oats, and clover (or soybeans). This gives an average return of $12.82 for each ton of phosphate applied. Averages for each rotation period show the following value of increase per ton of phosphate used:

	Lower prices	Higher prices
First rotation, 1903 to 1906	$ 8.26	$11.80
Second rotation, 1907 to 1910	11.33	16.19
Third rotation, 1911 to 1914	18.88	26.97

Thus the rock phosphate paid back more than its cost during the first rotation, more than 1½ times its cost during the second rotation, and more than 2½ times its cost during the third rotation period.

One ton of fine-ground rock phosphate costs about the same as 500 pounds of steamed bone meal. Altho in less readily available form, the rock phosphate contains as much phosphorus, ton for ton, as the bone meal; and, when equal money values are applied in connection with liberal amounts of decaying organic matter, the natural rock may soon give as good results as the bone,—and, by supplying about four times as much phosphorus, the rock provides for greater durability.

The results just given represent averages covering the residue system and the live-stock system, both of which are represented in this crop rotation on the South Farm.

Ground limestone at the rate of 8 tons per acre was applied to the east half of these series of plots (excepting the check plots, which receive only residues or manure), beginning in 1910 on Series 200 and in 1911 on Series 100. Subsequent applications are made of 2 tons per acre each four years, beginning in 1914 on Series 200 and in 1915 on Series 100. As an average of results from both series, the crop values were increased during the third rotation, 1911-1914, as follows:

	Residue System		Live-Stock System	
	Lower prices	Higher prices	Lower prices	Higher prices
Gain for phosphate	$18.80	$26.86	$18.96	$27.09
Gain for limestone	2.31	3.30	2.55	3.64

Detailed records of these investigations are given in Tables 5 and 6, the data being reported by half-plots after 1910-1911. (Series 300 and 400, which are also used in this rotation, are located in part upon black clay loam and a heavy phase of brown silt loam. See discussion under "Black Clay Loam," page 26.)

Results of Experiments on Sibley Field

Table 7 gives the results obtained during twelve years from the Sibley soil experiment field located in Ford county on the typical brown silt loam prairie of the Illinois corn belt.

Previous to 1902 this land had been cropped with corn and oats for many years under a system of tenant farming, and the soil had become somewhat deficient in active organic matter. While phosphorus was the limiting element of plant food, the supply of nitrogen becoming available annually was but little in excess of the phosphorus, as is well shown by the corn yields for 1903, when the addition of phosphorus produced an increase of 8 bushels, nitrogen produced no increase, but nitrogen *and* phosphorus increased the yield by 15 bushels.

After six years of additional cropping, however, nitrogen appeared to be-

TABLE 5.—YIELDS AND VALUES IN SOIL EXPERIMENTS, UNIVERSITY SOUTH FARM
COMMON BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Series 100		Corn 1903	Corn 1904	Oats 1905	Wheat 1906	Clover 1907	Corn 1908	Oats 1909	Clover 1910	Wheat[2] 1911	Corn 1912	Oats 1913	Soy-beans 1914	Value 1st four years		Value 2d four years		Value 3d four years	
Plot	Soil treatment applied	Bushels or tons per acre[1]												Lower prices	Higher prices	Lower prices	Higher prices	Lower prices	Higher prices
163	RP	45.1	54.1	57.5	39.8	(.83)	72.0	45.4	(.60)	46.85	74.9	26.8	(16.6)	$78.68	$112.40	$47.92	$68.46	$78.13	$111.62
166	RP	43.8	49.3	60.9	36.5	(1.00)	74.9	40.8	(1.30)	53.40	79.5	24.6	(17.5)	75.19	107.41	53.74	76.77	84.34	120.49
169	R	42.7	39.5	49.3	28.4	(.90)	65.0	39.9	(1.70)	36.71	67.9	19.1	(15.3)	62.45	89.22	52.12	74.46	65.52	93.60
170	M	41.8	38.7	52.2	26.2	2.56	69.6	40.1	2.87	35.85	76.7	22.5	1.09	61.13	87.33	73.60	105.14	65.87	94.10
173	MP	35.4	53.3	54.6	32.8	3.65	78.4	39.8	4.23	52.65	83.7	29.6	1.45	69.29	98.99	93.74	133.92	84.59	120.84
176	MP	39.3	58.1	61.9	38.8	3.74	79.5	40.0	4.23	51.03	85.6	32.1	1.52	78.58	112.26	94.81	135.45	85.30	121.87
163	RLP	.....	.....	.....	.....	.....	.....	.....	.....	49.9	87.0	28.2	(18.1)	.....	.....	.....	.....	85.94	122.78
166	RLP	.....	.....	.....	.....	.....	.....	.....	.....	53.6	81.4	26.8	(18.0)	.....	.....	.....	.....	86.11	123.02
169	R	.....	.....	.....	.....	.....	.....	.....	.....	33.8	62.7	17.0	(15.2)	.....	.....	.....	.....	61.00	87.15
170	M	.....	.....	.....	.....	.....	.....	.....	.....	32.4	74.4	22.0	1.09	.....	.....	.....	.....	62.51	89.30
173	MLP	.....	.....	.....	.....	.....	.....	.....	.....	51.3	85.7	28.0	1.37	.....	.....	.....	.....	83.33	119.05
176	MLP	.....	.....	.....	.....	.....	.....	.....	.....	51.0	85.6	30.9	1.47	.....	.....	.....	.....	84.60	120.86

[1]For legumes, figures in parentheses indicate bushels of seed; the others, tons of hay.
[2]From 1911 the acre-yields are based on half-plots, limestone having been applied to one half of plots indicated.

Table 6.—Yields and Values in Soil Experiments, University South Farm
Common Brown Silt Loam Prairie; Early Wisconsin Glaciation

Series 200		Oats 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Oats 1908	Wheat 1909	Wheat[2] 1910	Corn 1911	Oats 1912	Soy-beans 1913	Wheat 1914	Value 1st four years		Value 2d four years		Value 3d four years	
Plot	Soil treatment applied	Bushels or tons per acre[1]												Lower prices	Higher prices	Lower prices	Higher prices	Lower prices	Higher prices
263	RP	24.7	25.7	32.1	.82	65.3	31.3	42.5	43.7	52.3	72.9	(13.7)	30.61	$42.32	$60.46	$91.96	$131.37	$69.73	$99.62
266	RP	23.1	24.5	29.3	.80	59.7	26.7	40.7	32.3	50.2	75.7	(12.3)	33.86	39.43	56.34	79.47	113.53	71.08	101.54
269	R	26.8	22.5	26.8	.86	57.9	31.5	39.4	25.3	35.5	61.9	(10.7)	16.11	38.58	55.12	74.38	106.25	48.52	69.32
270	M	22.0	21.5	24.0	.82	55.3	30.0	37.1	28.7	43.1	67.8	.84	17.40	34.72	49.60	73.81	105.45	52.12	74.47
273	MP	23.9	25.0	27.8	.77	62.5	29.5	43.4	43.7	38.6	69.4	1.17	37.16	38.54	55.06	91.10	130.15	67.14	95.92
276	MP	16.1	25.3	30.7	.68	58.0	27.9	44.1	38.2	48.0	68.6	1.34	41.98	37.84	54.06	85.72	122.46	74.77	106.82
263	RLP								49.0	50.3	78.9	(13.2)	40.36					77.19	110.27
266	RLP								45.2	47.1	78.7	(10.3)	36.01					70.93	101.34
269	R								35.3	45.3	68.4	(10.5)	20.71					56.85	81.22
270	M								33.3	45.2	73.2	1.12	20.06					58.20	83.14
273	MLP								46.2	53.7	69.0	1.27	46.23					79.37	113.38
279	MLP								39.5	50.6	69.5	1.24	48.98					80.13	114.48

[1]For legumes, figures in parentheses indicate bushels of seed; the others tons of hay.
[2]From 1910 the acre-yields are based on half-plots, limestone having been applied to one half of plots indicated.

come the most limiting element, the increase in the corn in 1907 being 9 bushels from nitrogen and only 5 bushels from phosphorus, while both together produced an increase of 33 bushels. By comparing the corn yields for the four years 1902, 1903, 1906, and 1907, it will be seen that the untreated land apparently grew less productive, whereas, on land receiving both phosphorus and nitrogen, the yield appreciably increased, so that in 1907, when the untreated rotated land produced only 34 bushels of corn per acre, a yield of 72 bushels (more than twice as much) was produced where lime, nitrogen, and phosphorus had been applied, altho the two plots produced exactly the same yield (57.3 bushels) in 1902.

TABLE 7.—CROP YIELDS IN SOIL EXPERIMENTS, SIBLEY FIELD

Brown silt loam prairie; early Wisconsin glaciation		Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912	Wheat 1913
Plot	Soil treatment applied	Bushels per acre											
101	None	57.3	50.4	74.4	29.5	36.7	33.9	25.9	25.3	26.6	20.7	84.4	5.5
102	Lime	60.0	54.0	74.7	31.7	39.2	38.9	24.7	28.8	34.0	22.2	85.6	6.8
103	Lime, nitro.	60.0	54.3	77.5	32.8	41.7	48.1	36.3	19.0	29.0	22.4	25.3	18.3
104	Lime, phos.	61.3	62.3	92.5	36.3	44.8	43.5	25.6	32.2	52.0	31.6	92.3	10.7
105	Lime, potas.	56.0	49.9	74.4	30.2	37.5	34.9	22.2	23.2	34.2	21.6	83.1	7.5
106	Lime, nitro., phos.	57.3	69.1	88.4	45.2	68.5	72.3	45.6	33.3	55.6	35.3	42.2	24.7
107	Lime, nitro., potas.	53.3	51.4	75.9	37.7	39.7	51.1	42.2	25.8	46.2	20.1	55.6	19.2
108	Lime, phos., potas.	58.7	60.9	80.0	39.8	41.5	39.8	27.2	28.5	43.0	31.8	79.7	11.8
109	Lime, nitro., phos., potas.	58.7	65.9	82.5	48.0	69.5	80.1	52.8	35.0	58.0	35.7	57.2	24.5
110	Nitro., phos., potas.	60.0	60.1	85.0	48.5	63.3	72.3	44.1	30.8	64.4	31.5	54.1	18.0

Increase: Bushels per Acre

For nitrogen	.0	.3	2.8	1.1	2.5	9.2	11.6	–9.8	–5.0	.2	-60.3	11.5
For phosphorus	1.3	8.3	17.8	4.6	5.6	4.6	.9	3.4	18.0	9.4	6.7	3.9
For potassium	–4.0	–4.1	–.3	–1.5	–1.7	–4.0	–2.5	–5.6	.2	–.6	–2.5	.7
For nitro., phos. over phos.	–4.0	6.8	–4.1	8.9	23.7	28.8	20.0	1.1	3.6	3.7	-50.1	14.0
For phos., nitro. over nitro	–2.7	14.8	10.9	12.4	24.8	24.2	9.3	14.3	26.6	12.9	16.9	6.4
For potas., nitro., phos. over nitro., phos.	1.4	–3.2	–5.9	2.8	1.0	7.8	7.2	1.7	2.4	.4	15.0	–.2

Value of Crops per Acre in Twelve Years

Plot	Soil treatment applied	Total value of twelve crops	
		Lower prices	Higher prices
101	None	$172.89	$246.98
102	Lime	186.51	266.45
103	Lime, nitrogen	177.44	253.49
104	Lime, phosphorus	217.78	311.11
105	Lime, potassium	167.32	239.03
106	Lime, nitrogen, phosphorus	246.91	352.73
107	Lime, nitrogen, potassium	198.16	283.08
108	Lime, phosphorus, potassium	204.90	292.71
109	Lime, nitrogen, phosphorus, potassium	257.91	368.45
110	Nitrogen, phosphorus, potassium	242.47	346.38

Value of Increase per Acre in Twelve Years

For nitrogen	$ 9.07	$12.96
For phosphorus	31.27	44.66
For *nitrogen* and phosphorus over phosphorus	29.13	41.62
For *phosphorus* and nitrogen over nitrogen	69.47	99.24
For *potassium*, nitrogen, and phosphorus over nitrogen and phosphorus	11.00	15.72

Even in the unfavorable season of 1910 the yield of the highest producing plot exceeded the yield of the same plot in 1902, while the untreated land produced less than half as much as it produced in 1902. The prolonged drouth of 1911 resulted in almost a failure of the corn crop, but nevertheless the effect of soil treatment was seen. Phosphorus appeared to be the first limiting element again in 1909, 1910. and 1911; while the lodging of oats, especially on the nitrogen plots, in the exceptionally favorable season of 1912, produced very irregular results. In 1913, wheat averaged 6.6 bushels without nitrogen or phosphorus (Plots 101, 102, 105) and 22.4 bushels where both nitrogen and phosphorus were added (Plots 106, 109, 110).

In the lower part of Table 7 are shown the total values per acre of the twelve crops from each of the ten different plots, the amounts varying from $167.32 to $257.91, with corn valued at 35 cents a bushel, oats at 28 cents, and wheat at 70 cents. Phosphorus without nitrogen has produced $31.27 in addition to the increase by lime, but with nitrogen it has produced $69.47 above the crop values where only lime and nitrogen have been used. The results show that in 26 cases out of 48 the addition of potassium has decreased the crop yields. Even when applied in addition to phosphorus, and with no effort to liberate potassium from the soil by adding organic matter, potassium has produced no increase in crop values as an average of the results from Plots 108 and 109.

By comparing Plots 101 and 102, and also 109 and 110, it is seen that lime has produced an average increase of $14.53, or $1.21 an acre a year. This increase on these plots is practically the same as at Urbana, and it suggests that the time is here when limestone must be applied to some of these brown silt loam soils.

While nitrogen, on the whole, has produced an appreciable increase, especially on those plots to which phosphorus has also been added, it has cost, in commercial form, so much above the value of the increase produced that the only conclusion to be drawn, if we are to utilize this fact to advantage, is that the nitrogen must be secured from the air.

RESULTS OF EXPERIMENTS ON BLOOMINGTON FIELD

Space is taken to insert Tables 8 and 9, giving all results thus far obtained from the Bloomington soil experiment field, which is also located on the brown silt loam prairie soil of the Illinois corn belt. This field is a part of the S. Noble King farm.

The general results of the thirteen years' work tell much the same story as those from the Sibley field. The rotations have differed since 1905 by the use of clover and the discontinuing of the use of commercial nitrogen,—in consequence of which phosphorus without commercial nitrogen, on the Bloomington field, has produced an even larger increase ($99.85) than has been produced by phosphorus and nitrogen over nitrogen on the Sibley field ($69.47).

It should be stated that a draw runs near Plot 110 on the Bloomington field, that the crops on that plot are sometimes damaged by overflow or imperfect drainage, and that Plot 101, occupies the lowest ground on the opposite side of the field. In part because of these irregularities and in part because only one small application has been made, no conclusions can be drawn in regard to lime. Otherwise all results reported in Table 8 are considered reliable. They not only

furnish much information in themselves, but they also offer instructive comparison with the Sibley field.

Wherever nitrogen has been provided, either by direct application or by the use of legume crops, the addition of the element phosphorus has produced very marked increases, the average yearly increase for the Bloomington field being worth $7.02 an acre. This is $4.52 above the cost of the phosphorus in 200 pounds of steamed bone meal, the form in which it is applied on the Sibley and the Bloomington fields. On the other hand, the use of phosphorus without nitrogen will not maintain the fertility of the soil (see Plots 104 and 106, Sibley field). As the only practical and profitable method of supplying nitrogen, a liberal use of clover or other legumes is suggested, the legume to be plowed under either directly or as manure, preferably in connection with the phosphorus applied, especially if raw rock phosphate is used.

From the soil of the best treated plots on the Bloomington field, 180 pounds per acre of phosphorus, as an average, has been removed in the thirteen crops. This is equal to 15 percent of the total phosphorus contained in the surface soil of an acre of the untreated land. In other words, if such crops could be grown for eighty years, they would require as much phosphorus as the total supply in the ordinary plowed soil. The results plainly show, however, that without the addition of phosphorus such crops cannot be grown year after year. Where no phosphorus has been applied, the crops have removed only 120 pounds of phosphorus in the thirteen years, which is equivalent to only 10 percent of the total amount (1,200 pounds) present in the surface soil at the beginning of the experiment in 1902. The total phosphorus applied from 1902 to 1914, as an average of all plots where it has been used, has amounted to 325 pounds per acre and has cost $32.50.[1] This has paid back $97.20, or 300 percent on the invest-

Plate 5.—Corn in 1912 on Bloomington Field
On Left, Residues, Lime, and Potassium: Yield, 58.9 Bushels
On Right, Residues, Lime, and Phosphorus: Yield, 86.1 Bushels

[1]This is based on $25 a ton for steamed bone meal, but in recent years the price has been advanced generally to nearly $30.

TABLE 8.—CROP YIELDS IN SOIL EXPERIMENTS, BLOOMINGTON FIELD

Plot	Brown silt loam prairie; early Wisconsin glaciation Soil treatment applied	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Corn 1908	Oats 1909	Clover[2] 1910	Wheat 1911	Corn 1912	Corn 1913	Oats 1914
		Bushels or tons per acre												
101	None	30.8	63.9	54.8	30.8	.39	60.8	40.3	46.4	1.56	22.5	55.2	32.4	29.8
102	Lime	37.0	60.3	60.8	28.8	.58	63.1	35.3	53.6	1.09	22.5	47.9	30.0	40.6
103	Lime, crop residues[1]	35.1	59.5	69.5	30.5	.46	64.3	36.9	49.4	(.83)	25.6	62.5	37.5	30.8
104	Lime, phosphorus	41.7	73.0	72.7	39.2	1.65	82.1	47.5	63.8	4.21	57.6	74.5	44.1	45.0
105	Lime, potassium	37.7	56.4	62.5	33.2	.51	64.1	36.2	45.3	1.26	21.7	57.8	32.1	35.8
106	Lime, residues,[1] phosphorus	43.9	77.6	85.3	50.9	([3])	78.9	45.8	72.5	(1.67)	60.2	86.1	50.4	62.3
107	Lime, residues,[1] potassium	40.4	58.9	66.4	29.5	.81	64.3	31.0	51.1	(.33)	27.3	58.9	34.5	34.5
108	Lime, phosphorus, potassium	50.1	74.8	70.3	37.8	2.36	81.4	57.2	59.5	3.27	54.0	79.2	49.4	63.1
109	Lime, residues,[1] phosphorus, potassium	52.7	80.9	90.5	51.9	([3])	88.4	58.1	64.2	(.42)	60.4	83.4	49.0	54.4
110	Residues, phosphorus, potassium	52.3	73.1	71.4	51.1	([3])	78.0	51.4	55.3	(.60)	61.0	78.3	33.8	44.8
	Increase: Bushels or Tons per Acre													
	For residues	-1.9	-.8	9.0	1.7	-.12	1.2	1.6	-4.2		3.1	14.6	7.5	-9.8
	For phosphorus	4.7	12.7	11.9	10.4	1.07	19.0	12.2	10.2	3.12	35.1	26.6	14.1	4.4
	For potassium	.7	-3.9	1.7	4.4	-.07	1.0	.9	-8.3	.15	-.8	9.9	2.1	-4.8
	For residues, phosphorus over phosphorus	2.2	4.6	12.6	11.7	-1.65	-3.2	-1.7	8.7		2.6	11.6	6.3	17.3
	For phosphorus, residues over residues	8.8	18.1	15.5	20.4	-.46	14.6	8.9	23.1	(.84)	34.6	23.6	12.9	31.5
	For potassium, residues, phosphorus, over res., phos.	8.8	3.3	5.2	1.0	.00	9.5	12.3	-8.3	(-1.25)	.2	-2.7	-1.4	-7.9

[1]Commercial nitrogen was used 1902-1905.
[2]The figures in parentheses mean bushels of seed; the others, tons of hay.
[3]Clover smothered by previous wheat crop.

Table 9.—Value of Crops per Acre in Thirteen Years, Bloomington Field

Plot	Soil treatment applied	Total value of thirteen crops	
		Lower prices	Higher prices
101	None	$186.83	$266.90
102	Lime	186.76	266.80
103	Lime, residues	193.83	276.90
104	Lime, phosphorus	286.61	409.45
105	Lime, potassium	190.53	272.19
106	Lime, residues, phosphorus	285.03	407.19
107	Lime, residues, potassium	191.10	273.00
108	Lime, phosphorus, potassium	294.91	421.31
109	Lime, residues, phosphorus, potassium	284.47	406.39
110	Residues, phosphorus, potassium	259.10	370.15

Value of Increase per Acre in Thirteen Years

For residues	$ 7.07	$ 10.10
For phosphorus	99.85	142.65
For *residues* and phosphorus over phosphorus	–1.58	–2.26
For *phosphorus* and residues over residues	91.20	130.29
For *potassium,* residues, and phosphorus over residues and phosphorus	–.56	–.80

ment; whereas potassium, used in the same number of tests and at the same cost, has paid back only $2.20 per acre in the thirteen years, or less than 7 percent of its cost. Are not these results to be expected from the composition of such soil and the requirements of crops? (See Table 2; also Table A in the Appendix.)

Nitrogen was applied to this field, in commercial form only, from 1902 to 1905; but clover was grown in 1906 and 1910, and a cover crop of cowpeas after the clover in 1906. The cowpeas were plowed under on all plots, and the 1910 clover (except the seed) was plowed under on five plots (103, 106, 107, 109, and 110). Straw and corn stalks have also been returned to these plots in recent years. The effect of returning these residues to the soil has been appreciable since 1910 (an average increase on Plots 106 and 109 of 4.5 bushels of wheat, 5.4 bushels of corn, and 4.3 bushels of oats) and probably will be more marked on subsequent crops. Indeed, the large crops of corn, oats, and wheat grown on Plots 104 and 108 during the thirteen years have drawn their nitrogen very largely from the natural supply in the organic matter of the soil. The roots and stubble of clover contain no more nitrogen than the entire plant takes from the soil alone, but they decay rapidly in contact with the soil and probably hasten the decomposition of the soil humus and the consequent liberation of the soil nitrogen. But of course there is a limit to the reserve stock of humus and nitrogen remaining in the soil, and the future years will undoubtedly witness a gradually increasing difference between Plots 104 and 106, and between Plots 108 and 109, in the yields of grain crops.

Plate 6 shows graphically the relative values of the thirteen crops for the eight comparable plots, Nos. 102 to 109. The cost of the phosphorus is indicated by that part of the diagram above the short crossbars. It should be kept in mind that no value is assigned to clover plowed under except as it reappears in the increase of subsequent crops. Plots 106 and 109 are heavily handicapped because of the clover failure on those plots in 1906 and the poor yield of clover seed in 1910, whereas Plots 104 and 108 produced a fair crop in 1906 and a very

large crop in 1910. Plot 106, which receives the most practical treatment for permanent agriculture (RLP), has produced a total value in thirteen years only $1.58 below that from Plot 104 (LP). (See also table on last page of cover.)

The Subsurface and Subsoil

In Tables 10 and 11 are recorded the amounts of plant food in the subsurface and the subsoil of the different types of soil in McLean county, but it should be remembered that these supplies are of little value unless the top soil is kept rich. Probably the most important information contained in these tables is that the most common prairie soil and the upland timber soils are from slightly to strongly acid in the subsurface and sometimes contain no limestone in the subsoil. This fact emphasizes the importance of having plenty of limestone in the surface soil to neutralize the acid moisture which rises from the lower strata by capillary action during times of partial drouth, which are critical periods in the life of such plants as clover. While the common brown silt loam prairie is usually slightly acid, the upland timber soils are, as a rule, more distinctly in need of

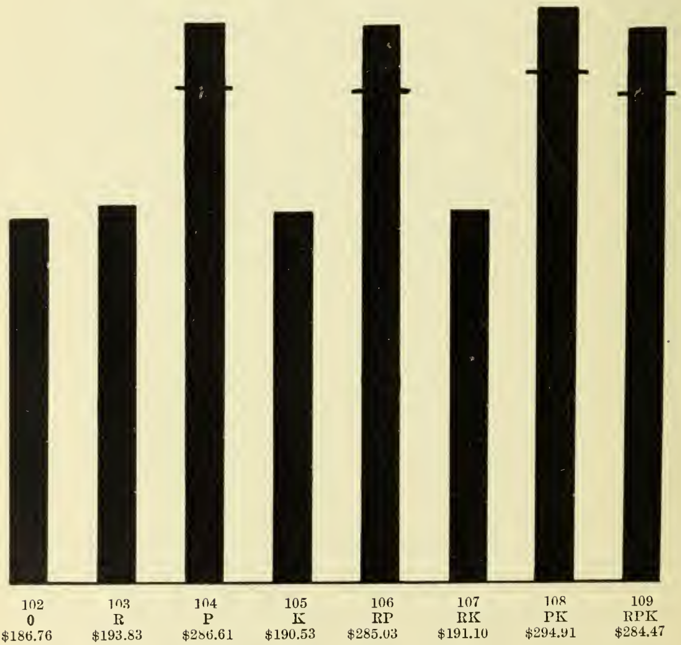

Plate 6.—Crop Values for Thirteen Years, Bloomington Experiment Field
(R=residues; P=phosphorus; K=potassium, or kalium)

limestone, and as already explained, they are also more deficient in organic matter and nitrogen than the prairie soils, and thus more in need of growing clover.

TABLE 10.—FERTILITY IN THE SOILS OF McLEAN COUNTY, ILLINOIS

Average pounds per acre in 4 million pounds of subsurface soil (about 6⅔ to 20 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity
	Upland Prairie Soils								
1126	Brown silt loam	74 530	6 660	1 870	73 230	19 520	17 850		110
1120	Black clay loam	91 180	8 130	3 150	70 760	33 150	57 190	Often	Rarely
1120.2	Gravelly black clay loam	65 200	6 240	2 600	67 880	46 640	106 200	252 200	
1128	Brown-gray silt loam on tight clay	27 720	3 200	2 160	78 960	17 640	12 040		880
1190	Gravelly loam	58 160	5 600	2 000	75 840	20 400	15 080		40
	Upland Timber Soils								
1134	Yellow-gray silt loam ...	24 490	2 710	1 490	74 230	16 390	13 980		2 350
1135	Yellow silt loam	15 280	2 020	1 540	72 000	24 620	14 620		3 660
	Terrace Soils								
1527	Brown silt loam over gravel	68 200	6 320	2 160	75 880	18 960	12 840		80
1526.2	Brown silt loam on gravel	55 320	5 160	1 640	83 780	22 600	14 340		100
1534.4	Yellow-gray silt loam on gravel	26 800	3 000	1 560	73 800	19 440	17 240		80
	Swamp and Bottom-Land Soils								
1401	Deep peat	608 090	52 420	4 610	14 160	11 080	63 270	Rarely	Often
1426	Deep brown silt loam...	144 760	11 520	3 320	69 280	22 080	34 920	1 360	
1454	Mixed loam	112 560	11 080	3 080	83 320	28 960	37 000	3 160	

TABLE 11.—FERTILITY IN THE SOILS OF McLEAN COUNTY, ILLINOIS

Average pounds per acre in 6 million pounds of subsoil (about 20 to 40 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity
	Upland Prairie Soils								
1126	Brown silt loam	32 310	3 620	2 350	114 870	48 600	46 360	Rarely	Often
1120	Black clay loam.........	35 480	3 450	3 410	111 560	58 820	80 450	Often	Rarely
1120.2	Gravelly black clay loam	47 760	4 140	3 120	104 220	54 540	119 520	279 300	
1128	Brown-gray silt loam on tight clay	21 900	3 120	3 540	120 600	36 240	19 500		840
1190	Gravelly loam	57 060	5 460	2 040	110 040	32 100	19 560		60
	Upland Timber Soils								
1134	Yellow-gray silt loam...	21 380	2 840	4 040	114 270	42 060	31 590		Often
1135	Yellow silt loam	20 250	2 580	3 000	110 820	58 650	60 510		Often
	Terrace Soils								
1527	Brown silt loam over gravel	36 120	3 840	2 520	106 800	39 540	22 320		420
1526.2	Brown silt loam on gravel	42 690	4 470	2 130	113 040	37 380	24 300		Often
1534.4	Yellow-gray silt loam on gravel	28 800	3 180	2 700	103 620	30 360	27 180		420
	Swamp and Bottom-Land Soils								
1401	Deep peat	752 400	55 050	4 650	38 010	20 490	71 910		30
1426	Deep brown silt loam....	86 880	5 640	3 180	108 600	27 720	47 220		120
1454	Mixed loam	101 280	9 900	3 120	123 900	43 320	49 200		60

INDIVIDUAL SOIL TYPES

(a) UPLAND PRAIRIE SOILS

The upland prairie soils of McLean county occupy 1,022.68 square miles, or 87.64 percent of the entire area of the county. They are black or brown in color, owing to their large content of organic matter.

The accumulation of organic matter in the prairie soils is due to the growth of prairie grasses whose network of roots was protected from complete decay by imperfect aeration due to the covering of fine soil material and the moisture it contained. On the native prairies, the tops of these grasses were usually burned or became almost completely decayed. From a sample of virgin sod of "blue stem," one of the most common prairie grasses, it has been determined that an acre of this soil to a depth of seven inches contained 13.5 tons of roots. Many of these roots died each year and by partial decay formed the humus of these dark prairie soils.

Brown Silt Loam (1126, *or* 926 *on moraines*)

Brown silt loam is the most important as well as the most extensive soil type in the county. It covers an area of 847.38 square miles (542,323 acres), or 72.6 percent of the entire county.

This type occupies the slightly undulating to rolling areas of the prairie land, much of which is well surface-drained, while many areas need artificial drainage. The morainal areas are sometimes sufficiently rolling to require considerable care in preventing erosion. Altho brown silt loam is normally a prairie soil, yet in some limited areas forests have recently invaded the dark soil. These forests consist quite largely of black walnut, wild cherry, hackberry, ash, hard maple, and elm. A black-walnut soil is recognized generally by farmers as being one of the best timber soils because of the fact that it still contains a large amount of organic matter, characteristic of prairie soils. After the growth of several generations of trees, the organic matter would become so reduced that the soil would then be classed as a timber type.

The surface soil, 0 to 6⅔ inches, is a brown silt loam, varying on the one hand to black as it grades into black clay loam (1120), and on the other hand to grayish brown or yellowish brown as it grades into the timber type, yellow-gray silt loam (1134 or 934). The physical composition varies to some extent, but it is normally a silt loam, containing from 65 to 80 percent of silt, together with some sand, and from 10 to 15 percent of clay. The amount of clay increases as the type approaches the black clay loam (1120), and becomes greatest in the level, poorly drained areas. The amount of sand varies from 10 to 20 percent.

The organic-matter content varies from 3.5 to 6.6 percent, with an average of 4.9 percent, or 49 tons per acre. The amount is less in the more rolling areas than in the low and poorly drained parts, owing to the fact not only that less vegetation grows on the drier, rolling areas, but that when incorporated with the soil much of it is removed by erosion and undergoes greater decomposition because of better aeration and less moisture. Where the type passes into the yellow-gray silt loam (1134 or 934), the organic-matter content becomes less, while in the low, swampy tracts where the grasses grew more luxuriantly and their

roots were more abundant, the large moisture content furnished conditions more favorable for the preservation of organic matter.

The natural subsurface is represented by a stratum varying from 6 to 16 inches in thickness, being thinner on the more rolling areas, while decidedly thicker and darker on the more level areas. Its physical composition varies in the same way as that of the surface soil, but it usually contains a slightly larger amount of clay, especially as it approaches the black clay loam type (1120). Both color and depth vary with the topography, the stratum being lighter in color as well as shallower on the more rolling areas and where the type grades into yellow-gray and yellow silt loam (1134 or 1135). The amount of organic matter varies with depth, but the average for this stratum (which is twice the thickness of the surface soil as it is sampled) is 3.2 percent, or 64 tons per acre.

The natural subsoil begins at 12 to 23 inches, and extends to an indefinite depth, but is sampled to 40 inches. It varies with the topography both in color and texture, and becomes slightly coarser with depth. It consists of a yellow or drabbish mottled yellow, clayey silt or silty clay, plastic when wet. Where the drainage has been good, it is of a bright to a pale yellow color. With poor drainage it approaches a drab or olive color with pale yellow mottlings or a yellow color with mottlings of drab. Each of the above strata is pervious to water, so that drainage takes place with little difficulty.

A phase of brown silt loam has been recognized in this county where, because of the removal of part of the fine loëssial material by erosion, the glacial drift is encountered less than 30 inches from the surface. If the drift is quite compact, as is occasionally the case, this gives rise to a somewhat inferior subsoil, owing to its less pervious character. This condition, however, does not occur very generally nor over large areas, since most of the drift is pervious and some is quite gravelly. This phase is found mostly in Township 23 North, Range 6 East.

In the northeastern part of the county a slightly sandy phase of the type is found, but it is not sufficiently sandy to be classed as a loam. Small areas of sandy and gravelly loam, too small to be shown on the map, are common in the most rolling part of the morainal regions.

An abnormal phase of brown silt loam about 30 acres in extent is found in the northeast forty of Section 11, Township 22 North, Range 5 East. In spots this varies a great deal from the true type, being a sandy peat in some places, a marly peat in others, and in still others containing large amounts of brown iron oxid.

While the common brown silt loam is in fair physical condition, yet continuous cropping to corn, or corn and oats, with the burning of the stalks, is destroying the tilth; the soil is becoming more difficult to work; it runs together more; and aeration, granulation, and absorption of moisture do not take place as readily as formerly. This condition of poor tilth may become serious if the present methods of management continue; it is already one of the factors that limit the crop yields. The remedy is to increase the organic-matter content by plowing under farm manure and crop residues, such as corn stalks, straw, and clover.

The addition of fresh organic matter is not only of great value in improving the physical condition of this type of soil, but it is of even greater importance because of its nitrogen content and because of its power, as it decays, to liberate potassium from the inexhaustible supply in the soil, and phosphorus from the phosphate contained in or applied to the soil.

For permanent, profitable systems of farming on brown silt loam, phosphorus should be applied liberally, and sufficient organic matter should be provided to furnish the necessary amount of nitrogen. On the ordinary type, limestone is already becoming deficient. An application of two tons of limestone and one-half ton of fine-ground rock phosphate per acre every four years, with the return to the soil of all manure made from a rotation of corn, corn, oats, and clover, will maintain the fertility of this type, altho heavier applications of phosphate may well be made during the first two or three rotations. If grain farming is practiced, the rotation may be wheat, corn, oats, and clover, with an extra seeding of clover as a cover crop in the wheat, to be plowed under late in the fall or in the following spring for corn; and most of the crop residues, with all clover except the seed, should also be plowed under. In either system, alfalfa may be grown on a fifth field and moved every five years, the hay being fed or sold. In live-stock farming the regular rotation may be extended to five or six years by seeding both timothy and clover with the oats, and pasturing one or two years. Alsike and sweet clover may well replace red clover at times, in order to avoid clover sickness. (For results of field experiments on the brown silt loam prairie, see Tables 3 to 9.)

Black Clay Loam (1120)

Black clay loam represents the flat prairie and is sometimes called "gumbo" because of its sticky character. Its formation in flatter, poorly drained areas is due to the accumulation of organic matter and to the washing in of clay and fine silt from the slightly higher adjoining lands. This type occupies 168.69 square miles (17,961 acres), or 14.47 percent of the entire area of the county. It is so flat that proper drainage is one of the most difficult problems in its management.

The surface soil, 0 to 6⅔ inches, is a black granular clay loam, varying locally to a black clayey silt loam on the large flat areas. It contains, on an average, 7.6 percent of organic matter, or 76 tons per acre, varying from 65 to 98 tons. In physical composition it varies somewhat as it grades into other types. As it passes toward the brown silt loam, which nearly always surrounds it, it becomes more silty. Where it merges into the gravelly black clay loam (1120.2), it sometimes contains considerable quantities of sand and fine or medium gravel.

The subsurface stratum has a thickness of 10 to 16 inches and varies from a black to a brownish gray clay loam, usually somewhat heavier than the surface soil. The average amount of organic matter is 4 percent, or 80 tons per acre. The lower part of this stratum frequently is a drab or yellowish drab silty clay. The stratum is quite pervious to water, owing to jointing or checking from shrinkage in times of drouth.

The subsoil to a depth of 40 inches varies from a drab to a yellowish drab silty clay. As a rule, the iron is not highly oxidized, because of poor drainage and lack of aeration. Concretions of carbonate of lime are frequently found. The perviousness of the subsoil is about the same as the subsurface and is due to the same cause. When thrown out on the surface where wetting and drying may take place, it soon breaks into small cubical masses. Gravel is frequently present.

Black clay loam presents many variations. Here, as elsewhere, the boundary lines between it and the brown silt loam are not always distinct. In some cases topography is a great help in locating the boundary, but in other cases there may be an intermediate zone of greater or less width. The washing in of silty

material from the surrounding higher lands, especially near the edges of the areas, modifies the character of the soil, giving the surface a silty character. This change is taking place more rapidly now, with the annual cultivation of the soil, than formerly, when washing was largely prevented by prairie grasses.

Drainage is the first requirement in the management of this type; altho it usually has but little slope, yet because of its perviousness it is easily tile-drained. Keeping the soil in good physical condition is very essential, and thoro drainage helps to do this to a great extent. As the organic matter is destroyed by cultivation and nitrification, and as the limestone is removed by cropping and leaching, the physical condition of the soil becomes poorer, and as a consequence it becomes more difficult to work. Both organic matter and limestone tend to develop granulation. The former should be maintained by turning under manure or such crop residues as corn stalks and straw, and by the use of clover and pasture in rotations. Ground limestone should be applied when needed to keep the soil sweet. It should be remembered that the difficulty of working clay soils is in proportion to their deficiency in organic matter.

While black clay loam is one of the best soils in the state, yet the clay and humus which it contains give it the property of shrinkage and expansion to such a degree as to be somewhat objectionable at times, especially during drouth. When the soil is wet, these constituents expand, and when the moisture evaporates or is used by crops, they shrink. This results in the formation of cracks, sometimes as much as two or more inches in width and extending with lessening width to two or three feet in depth. During the drouth of 1914, the cracks were so large and deep that in many cases a one-inch auger could be forced into them, without turning, to a depth of more than two feet. These cracks allow the soil strata to dry out rapidly, and as a result the crop is injured thru lack of moisture. They may do considerable damage by "blocking out" hills of corn and severing the roots. While cracking may not be prevented entirely, good tilth with a soil mulch will do much toward that end. Both for aeration and for producing a mulch for conserving moisture, cultivation is more essential on this type than on the brown silt loam. It must be remembered, however, that cultivation should be as shallow as possible, in order to prevent injury to the roots of the corn.

This type is fairly well supplied with plant food, which is usually liberated with sufficient rapidity by a good rotation and by the addition of moderate amounts of organic matter. The amount of organic matter added must be increased, of course, with continued farming, until the nitrogen supplied is equal to that removed. Altho the addition of phosphorus is not expected to produce marked profit, it is likely to pay its cost in the second or third rotation; and even by maintaining the productive power of the land, the capital invested is protected.

At Urbana, on the South Farm of the University of Illinois, a series of plots devoted chiefly to variety tests and other crop-production experiments extends across an area of black clay loam. Where rock phosphate has been applied at the rate of 500 pounds an acre a year in connection with crop residues, in a four-year rotation of wheat, corn, oats, and clover (or soybeans), the value of the increase produced per ton of phosphate used in three successive rotation periods, has been \$2.13, \$4.70, and \$6.48, respectively, at the "lower prices," or \$3.04, \$6.71, and \$9.26, respectively, at the "higher prices" for produce. In the live-stock system, the phosphorus naturally supplied in the manure, supple-

mented by that liberated from this fertile soil, has thus far been nearly sufficient to meet the crop requirements; the increase in crop values per ton of phosphate applied having been, as an average for the twelve years, only $2.26 at the "lower prices," or $3.26 at the "higher prices." These returns are less than half the cost of the phosphorus applied, and some seasons no benefit appears.

This type is rich in magnesium and calcium, and in the Wisconsin glaciation it usually contains plenty of carbonates. With continued cropping and leaching, applications of limestone will ultimately be needed.

Gravelly Black Clay Loam (1120.2)

Gravelly black clay loam occurs in the poorly drained areas in the eastern and northeastern part of the county in the large sloughs that, during parts of the year, were once covered with streams whose currents were sufficiently strong to carry and deposit considerable quantities of sand and small gravel. These materials have become mixed with the fine material and form a distinct phase of black clay loam.

The surface soil, 0 to 6⅔ inches, varies from 15 to 40 percent in the amount of gravel it contains, the gravel itself being mostly fine. The organic-matter content is not quite so high as in the black clay loam, being about 6.4 percent, or 64 tons per acre.

The subsurface, extending from 6⅔ to 18 or 20 inches, is a brown gravelly clay loam, containing about 3.2 percent of organic matter and passing at the lower limit into a less gravelly and much lighter colored clay loam.

The subsoil varies from a drab to a pale yellowish drab, indicating poor oxidation. It does not usually contain as much gravel as either the surface or subsurface. Limestone concretions are frequently found.

The management of this type is not different from that of the black clay loam, altho there may be a greater necessity for maintaining the supply of organic matter because of the lower content of this constituent naturally in the soil. The presence of gravel affects the working of the soil only to a slight extent, since clay possesses such distinctive properties that it takes a large amount of gravel and sand to overcome its effects. Hence this type works very little differently from the ordinary black clay loam.

Brown-Gray Silt Loam on Tight Clay (1128)

Brown-gray silt loam on tight clay occurs in numerous small areas thruout the county, principally in Township 23 North, Ranges 1 West and 1 East; also in the southwestern part of Township 24 North, Range 1 West. The total area occupied by this type is 2.42 square miles (1,549 acres), or .2 percent of the area of the county. While not of great importance from the standpoint of area, yet it is interesting to note that the tight clay soils, or so-called hardpan, have developed under certain conditions even in the early Wisconsin glaciation. The topography is flat and naturally poorly drained.

The surface soil, 0 to 6⅔ inches, consists of a brown or grayish brown silt loam, containing some fine sand and coarse silt, which give it a peculiar, mealy feel but excellent texture. It contains about 4 percent of organic matter, or 40 tons per acre, and is somewhat richer in this constituent than the corresponding

type in southern Illinois. The organic-matter content varies with its relation to other types, being greater where it approaches brown silt loam (1126) and less where it passes into yellow-gray silt loam (1134). As a rule, the surface soil is not so granular as the ordinary brown silt loam.

The subsurface is represented by a stratum 10 to 12 inches thick. The color varies from a brown to a gray or grayish brown, the upper part of the stratum usually being brown, while the lower part is decidedly gray or grayish brown. It differs from the surface soil principally in the amount of organic matter it contains, having 1.2 percent as compared with 4 percent in the top stratum.

The natural subsoil begins at a depth of 16 to 18 inches, as a yellowish, almost impervious, silty clay, and has a thickness of 10 to 15 inches. It is usually underlain by a rather pervious silt. This tight clay layer obstructs drainage to such an extent that percolation is not very rapid, hence the soil dries very slowly. The land should be tiled thoroly, unless surface drainage is sufficient. In order to do this, the lines of tile should be placed not over four rods apart.

Care should be taken, on this type, to maintain or increase the amount of organic matter by the proper rotation of crops and the turning under of crop residues and farm manures. Deep-rooting crops, such as red, mammoth, and sweet clover, should be grown so as to render the tight clay more permeable to air and water.

From Table 2 it will be seen that the surface soil contains only 4,200 pounds of nitrogen and 1,380 pounds of phosphorus per acre. To increase these amounts, liberal applications of fine-ground rock phosphate should be made in connection with decaying organic matter, as on the brown silt loam. This type is distinctly acid in surface, subsurface, and subsoil. Limestone should be applied at the rate of 2 to 3 tons per acre every four to six years. The initial applications may well be 1 ton of phosphate and 4 tons of limestone.

Gravelly Loam (1190 *or* 990)

Gravelly loam occupies many areas on the upland but covers a total of only 96 acres. These areas are small and isolated, representing small gravel ridges recently covered by fine wind-blown material.

The organic matter of the soil should be maintained, and in other respects the treatment should be the same as for the brown silt loam, except that phosphorus need not be added, because of the deep feeding range afforded plant roots.

(b) Upland Timber Soils

The upland timber soils occur along streams, or, in some cases, on or near somewhat steep morainal ridges. They are characterized by a yellow, yellowish gray, or gray color, due to their low organic-matter content. This lack of organic matter has been caused by the long-continued growth of forest trees. As the forests invaded the prairies, two effects were produced: (1) the shading of the trees prevented the growth of prairie grasses, the roots of which are mainly responsible for the large amount of organic matter in prairie soils; (2) the trees themselves added very little organic matter to the soil, for the leaves and branches either decayed completely or were burned by forest fires. As a result the organic-matter content of the upland timber soils has been reduced until in some parts of the state a low condition of apparent equilibrium has been reached.

Yellow-Gray Silt Loam (1134 *or* 934)

Yellow-gray silt loam occurs in the outer timber belts along streams and in the less rolling of the timbered morainal areas. The type covers 73.42 square miles (46,989 acres), or 6.23 percent of the entire area of the county. In topography it is sufficiently rolling for good surface drainage, without much tendency to wash if proper care is taken.

The surface soil, 0 to 6⅔ inches, is a yellow, yellowish gray, gray, or brownish gray silt loam, incoherent but not granular. The more nearly level areas are gray in color, while the more rolling phase of the type has a yellow or brownish yellow color. As the type approaches the brown silt loam, it becomes decidedly darker. The organic-matter content averages 2.9 percent, or 29 tons per acre, but it varies considerably with topography. As the type approaches the brown silt loam, the organic matter amounts to as much as 3.8 percent, while as it approaches the yellow silt loam, it diminishes to as low as 2.3 percent. In some cases it is extremely difficult to draw the line between the long-cultivated brown silt loam and the yellow-gray silt loam, because of the gradation between the types.

The subsurface stratum varies from 3 to 10 inches in thickness, erosion having reduced its thickness on the more rolling areas. It is usually a gray, grayish yellow, or yellow silt loam, somewhat pulverulent, but becoming more coherent and plastic with depth. The amount of organic matter is about 1 percent, or 20 tons per acre in the four million pounds of soil.

The subsoil is a yellow or mottled grayish yellow, clayey silt or silty clay, somewhat plastic when wet, but friable when only moist, and pervious to water. Glacial drift is sometimes encountered at a depth of less than 40 inches. This is due to the removal by erosion of part of the loessial material. The glacial drift may be locally a very gravelly deposit, but usually it is a slightly gravelly clay and in some places is lacking in permeability. Otherwise, each stratum of this type is quite pervious to water, except in the level gray areas, where the tight and more or less compact clayey layer has been formed at a depth of 18 to 24 inches. Small areas of light gray silt loam on tight clay are found in the county, but none large enough to be shown on the map.

In the management of this type one of the most essential things is the maintaining or the increasing of organic matter. This is necessary in order to supply nitrogen and liberate mineral plant food, to give better tilth, to prevent "running together," and on some of the more rolling phases, to prevent washing.

Another essential is the neutralization of the acidity of the soil by the application of ground limestone, so that clover, alfalfa, and other legumes may be grown more successfully. The initial application may well be 4 or 5 tons per acre, after which 2 tons per acre every four or five years will be sufficient. Since the soil is poor in phosphorus, this element should be applied, preferably in connection with farm manure or clover plowed under. In permanent systems of farming, fine-ground natural rock phosphate will be found the most economical form in which to supply the phosphorus, altho steamed bone meal or acid phosphate may well be used temporarily until plenty of decaying organic matter can be provided.

For definite results from the most practical field experiments upon typical yellow-gray silt loam, we must go down into "Egypt," where the people of Saline county, especially those in the vicinity of Raleigh and Galatia, have provided

the University with a very suitable tract of this type of soil for a permanent experiment field. There, as an average of duplicate trials each year for the four years 1911 to 1914, the crop values from four acres were $16.44 from untreated land, $18.22 where organic manures were applied in proportion to the amount of crops produced, and $33.58 where 6 tons per acre of limestone and the organic manures were applied,—the wheat, corn, oats, and clover (or cowpeas or soybeans) grown in the rotation being valued at the "lower prices" heretofore mentioned. Owing to the low supply of organic matter, phosphorus produced almost no benefit, as an average, during the first two years; but with increasing applications of organic matter, the effect of phosphorus is becoming more apparent in subsequent crops. Of course the full benefit of a four-year rotation cannot be realized during the first four years. The farm manure was applied to one field each year, and the fourth field received no manure until the fourth year. Likewise, crop residues plowed under during the first rotation may not be fully recovered in subsequent increased yields until the second or third rotation period.

While limestone is the material first needed for the economic improvement of the more acid soils of southern Illinois, with organic manures and phosphorus to follow in order, the less acid soils of the central part of the state are first in need of phosphorus, altho limestone and organic matter must also be provided for permanent and best results.

Table 12 shows in detail thirteen years' results secured from the Antioch soil experiment field located in Lake county on the yellow-gray silt loam of the late Wisconsin glaciation. In acidity this type in McLean county is intermediate between the similar soils in Saline and Lake counties, but no experiment field has been conducted on this important soil type in the early Wisconsin glaciation, in which McLean county is situated.

The Antioch field was started in order to learn as quickly as possible what effect would be produced by the addition to this type of soil, of nitrogen, phosphorus, and potassium, singly and in combination. These elements were all added in commercial form until 1911, after which the use of commercial nitrogen was discontinued and crop residues were substituted in its place. (See report of Urbana field for further explanations, page 7.) Only a small amount of lime was applied at the beginning, in harmony with the teaching which was common at that time; furthermore, Plot 101 proved to be abnormal, so that no conclusions can be drawn regarding the effect of lime. In order to ascertain the effect produced by additions of the different elements singly, Plot 102 must be regarded as the check plot. Three other comparisons are also possible to determine the effect of each element under different conditions.

As an average of 40 tests (4 each year for ten years), liberal applications of commercial nitrogen produced a slight decrease in crop values; but as an average of thirteen years each dollar invested in phosphorus paid back $2.54 (Plot 104), while potassium applied in addition to phosphorus (Plot 108) produced no increase, the crops being valued at the lower prices used in the tabular statement. Thus, while the detailed data show great variation, owing both to some irregularity of soil and to some very abnormal seasons, with three almost complete crop failures (1904, 1907, and 1910), yet the general summary strongly confirms the analytical data in showing the need of applying phosphorus and the profit from its use, and the loss in adding potassium. In most cases com-

TABLE 12.—CROP YIELDS IN SOIL EXPERIMENTS, ANTIOCH FIELD

Plot	Yellow-gray silt loam, undulating timberland; late Wisconsin glaciation / Soil treatment applied[1]	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912	Clover 1913[2]	Wheat 1914
		Bushels or tons per acre												
101	None	44.8	36.6	17.8	18.5	35.9	12.4	65.6	12.2	5.2	34.4	21.3	.50	30.8
102	Lime	45.1	38.9	12.8	10.3	31.5	9.5	61.6	11.7	3.0	24.6	17.5	.60	30.0
103	Lime, nitrogen	46.3	40.8	2.8	17.8	37.8	6.4	60.3	13.0	1.4	10.4	24.4	([3])	40.8
104	Lime, phosphorus	50.1	53.6	12.5	35.8	57.4	13.4	70.9	23.3	6.8	37.4	49.1	1.32	54.2
105	Lime, potassium	48.2	50.2	9.7	21.7	34.9	12.9	62.5	13.5	4.6	20.4	18.8	.72	34.0
106	Lime, nitrogen, phosphorus	56.6	62.7	15.9	15.2	59.3	20.9	49.1	33.8	6.0	37.0	46.9	([3])	41.3
107	Lime, nitrogen, potassium	52.1	54.9	10.3	11.8	39.0	11.1	52.6	21.0	1.6	7.0	16.9	([3])	43.2
108	Lime, phosphorus, potassium	60.7	66.0	19.7	28.7	59.1	18.3	59.4	26.2	3.2	42.2	35.9	1.60	46.0
109	Lime, nitrogen, phosphorus, potassium	61.2	69.1	31.9	18.0	65.9	31.4	51.9	30.5	3.0	44.2	31.9	([3])	41.0
110	Nitrogen, phosphorus, potassium	59.7	71.8	37.2	16.3	66.3	28.8	55.9	34.5	4.0	49.0	38.1	([3])	37.8
		Increase: Bushels or Tons per Acre												
	For nitrogen	1.2	1.9	–10.0	7.5	6.3	–3.1	–1.3	1.3	–1.6	–14.2	6.9		10.8
	For phosphorus	5.0	14.7	–.3	25.5	25.9	3.9	9.3	11.6	3.8	12.8	31.6	.72	24.2
	For potassium	3.1	11.3	–3.1	11.4	3.4	3.4	.9	1.8	1.6	–4.2	1.3	.12	4.0
	For nitrogen, phosphorus over phosphorus	6.5	9.1	3.4	–20.6	1.9	7.5	–21.8	10.5	–.8	–.4	2.2		–12.9
	For phosphorus, nitrogen over nitrogen	10.3	21.9	13.1	–2.6	21.5	14.5	–11.2	20.8	4.6	26.6	22.5		.5
	For postassium, nitrogen, phosphorus over nitrogen, phosphorus	4.6	6.4	16.0	2.8	6.6	10.5	2.8	–3.3	–3.0	7.2	–15.0		–.3

[1]Crop residues in place of commercial nitrogen after 1911.
[2]Figures in parentheses indicate bushels of seed; the others, tons of hay.
[3]No seed produced: clover plowed under on these plots.

TABLE 13.—VALUE OF CROPS PER ACRE IN THIRTEEN YEARS, ANTIOCH FIELD

Plot	Soil treatment applied	Total value of thirteen crops	
		Lower prices[1]	Higher prices[2]
101	None	$135.12	$193.03
102	Lime	119.74	171.06
103	Lime, nitrogen	124.70	178.15
104	Lime, phosphorus	202.20	288.85
105	Lime, potassium	138.88	198.40
106	Lime, nitrogen, phosphorus	179.41	256.31
107	Lime, nitrogen, potassium	133.54	190.77
108	Nitrogen, phosphorus, potassium	201.35	287.65
109	Lime, nitrogen, phosphorus, potassium	191.22	273.18
110	Nitrogen, phosphorus, potassium	181.18	258.83
	Value of Increase per Acre in Thirteen Years		
	For nitrogen	$ 4.96	$ 7.09
	For phosphorus	82.46	117.79
	For *nitrogen* and phosphorus over phosphorus	–22.79	–32.54
	For *phosphorus* and nitrogen over nitrogen	54.71	78.16
	For *potassium,* nitrogen, and phosphorus over nitrogen and phosphorus	11.81	16.87

[1]Wheat at 70 cents a bushel, corn at 35 cents, oats at 28 cents, hay at $7 a ton.
[2]Wheat at $1 a bushel, corn at 50 cents, oats at 40 cents, hay at $10 a ton.

mercial nitrogen damaged the small grains by causing the crop to lodge; but in those years when a corn yield of 40 bushels or more was secured by the application of phosphorus either alone or with potassium, then the addition of nitrogen produced an increase.

From a comparison of the results from the Urbana, Sibley, and Bloomington fields, we must conclude that better yields are to be secured by providing nitrogen by means of farm manure or legume crops grown in the rotation than by the use of commercial nitrogen, which is evidently too readily available, causing too rapid growth and consequent weakness of straw; and of course the atmosphere is the most economic source of nitrogen where that element is needed for soil improvement in general farming. (See Appendix for detailed discussion of "Permanent Soil Improvement.")

Yellow Silt Loam (1135 *or* 935)

Yellow silt loam covers 27.43 square miles (17,555 acres) and constitutes 2.36 percent of the entire area of the county. It occurs as the hilly and badly eroded land on the inner timber belts adjacent to the streams, usually only in narrow, irregular strips with arms extending up the small valleys. In topography it is very rolling, and in most places so badly broken that it should not be cultivated because of the danger of injury from washing.

The surface soil, 0 to 6⅔ inches, is a yellow or grayish yellow, pulverulent silt loam. It varies greatly in color and texture, owing to recent washing. In places the natural subsoil may be exposed. This exposure gives it a decidedly yellow color. The soil freshly plowed appears yellow or brownish yellow, but when it becomes dry after a rain, it is of a grayish color. In some places the surface soil is formed from glacial drift, but this is only on very limited areas and on the steepest slopes. The organic-matter content is the lowest of any type in the county, being only 1.5 percent, or 15 tons per acre. It varies, however, from 1.2 to 1.8 percent.

The subsurface varies from a yellow silt loam to a yellow clayey silt loam, and on the steepest slopes may consist of weathered glacial drift. The thickness of the stratum varies from 5 to 12 inches, depending on the amount of recent erosion. The organic-matter content amounts to only 12 tons per acre.

The subsoil consists normally of a yellow clayey silt, but in some areas may be composed entirely of glacial drift.

The first and most important thing in the management of this type is to prevent general surface washing and gullying. If the land is cropped at all, a rotation should be practiced that will require a cultivated crop as little as possible, and allow pasture and meadow most of the time. If tilled, the land should be plowed deeply and contours should be followed as nearly as possible in plowing, planting, and cultivating. Furrows should not be made up and down the slopes. Every means should be employed to maintain and increase the organic-matter content. This will help hold the soil and keep it in good physical condition so that it will absorb a large amount of water and thus diminish the run-off. (See Circular 119, ''Washing of Soils and Methods of Prevention.'')

Additional treatment recommended for this yellow silt loam is the liberal use of limestone wherever cropping is practiced. This type is quite acid and very deficient in nitrogen; and the limestone, by correcting the acidity of the soil, is especially beneficial to the clover grown to increase the supply of nitrogen. Where this soil has been long cultivated and thus exposed to surface washing, it is particularly deficient in nitrogen; indeed, on such lands the low supply of nitrogen is the factor that first limits the growth of grain crops. This fact is very strikingly illustrated by the results from two pot-culture experiments reported in Tables 14 and 15, and shown photographically in Plates 7 and 8.

In one experiment, a large quantity of the typical worn hill soil was collected from two different places.[1] Each lot of soil was thoroly mixed and put in ten four-gallon jars. Ground limestone was added to all the jars except the first and last in each set, those two being retained as control or check pots. The elements nitrogen, phosphorus, and potassium were added singly and in combination, as shown in Table 14.

As an average, the nitrogen applied produced a yield about eight times as large as that secured without the addition of nitrogen. While some variations in yield are to be expected, because of differences in the individuality of seed or other uncontrolled causes, yet there is no doubting the plain lesson taught by these actual trials with growing plants.

The question arises next, Where is the farmer to secure this much-needed nitrogen? To purchase it in commercial fertilizers would cost too much; indeed, under average conditions the cost of the nitrogen in such fertilizers is greater than the value of the increase in crop yields.

But there is no need whatever to purchase nitrogen, for the air contains an inexhaustible supply of it, which, under suitable conditions, the farmer can draw upon, not only without cost, but with profit in the getting. Clover, alfalfa, cowpeas, and soybeans are not only worth raising for their own sake, but they have the power to secure nitrogen from the atmosphere if the soil contains limestone and the proper nitrogen-fixing bacteria.

[1]Soil for wheat pots from loess-covered unglaciated area, and that for oat pots from upper Illinois glaciation.

To secure further information along this line, another experiment with pot cultures was conducted for several years with the same type of worn hill soil as that used for wheat in the former experiment. The results are reported in Table 15.

To three pots (Nos. 3, 6, and 9) nitrogen was applied in commercial form, at an expense amounting to more than the total value of the crops produced. In three other pots (Nos. 2, 11, and 12) a crop of cowpeas was grown during the late summer and fall and turned under before the wheat or oats were planted. Pots 1 and 8 served for important comparisons. After the second cover crop of cowpeas had been turned under, the yield from Pot 2 exceeded that from Pot 3; and in the subsequent years the legume green manures produced, as an average, rather better results than the commercial nitrogen. This experiment confirms that reported in Table 14, in showing the very great need of nitrogen for the improvement of this type of soil, and it also shows that nitrogen need not be purchased but that it can be obtained from the air by growing legume crops and plowing them under as green manure. Of course the soil can be very markedly improved by feeding the legume crops to live stock and returning the resulting

PLATE 7.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND (See Table 14)

TABLE 14.—CROP YIELDS IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND

(Grams per pot)

Pot No.	Soil treatment applied	Wheat	Oats
1	None	3	5
2	Limestone	4	4
3	Limestone, nitrogen	26	45
4	Limestone, phosphorus	3	6
5	Limestone, potassium	3	5
6	Limestone, nitrogen, phosphorus	34	38
7	Limestone, nitrogen, potassium	33	46
8	Limestone, phosphorus, potassium	2	5
9	Limestone, nitrogen, phosphorus, potassium	34	38
10	None	3	5
Average yield with nitrogen		32	42
Average yield without nitrogen		3	5
Average gain for nitrogen		29	37

farm manure to the land, if legumes are grown frequently enough and if the farm manure produced is sufficiently abundant and is saved and applied with care.

As a rule, it is not advisable to try to enrich this type of soil in phosphorus, for with the erosion that is sure to occur to some extent the phosphorus supply will be renewed from the subsoil.

Probably the best legumes for this type of soil are sweet clover and alfalfa. On soil deficient in organic matter sweet clover grows better than almost any other legume, and the fact that it is a very deep-rooting plant makes it of value in increasing organic matter and preventing washing. Worthless slopes that have been ruined by washing may be made profitable as pasture by growing sweet clover. The blue grass of pastures may well be supplemented by sweet clover and alfalfa, and a larger growth obtained, because the legumes provide the necessary nitrogen for the blue grass.

To get alfalfa well started requires the liberal use of limestone, thoro inoculation with nitrogen-fixing bacteria, and a moderate application of farm manure. If manure is not available, it is well to apply about 500 pounds per acre of acid phosphate, or steamed bone meal, mix it with the soil, by disking if possible, and then plow it under. The limestone (about 5 tons) should be applied after plowing and should be mixed with the surface soil in the preparation of the seed bed. The special purpose of this treatment is to give the alfalfa a quick start in order that it may grow rapidly and thus protect the soil from washing.

PLATE 8.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND (See Table 15)

TABLE 15.—CROP YIELDS IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND AND NITROGEN-FIXING GREEN MANURE CROPS

(Grams per pot)

Pot No.	Soil treatment	1903 Wheat	1904 Wheat	1905 Wheat	1906 Wheat	1907 Oats
1	None	5	4	4	4	6
2	Limestone, legume	10	17	26	19	37
11	Limestone, legume, phosphorus	14	19	20	18	27
12	Limestone, legume, phosphorus, potassium	16	20	21	19	30
3	Limestone, nitrogen	17	14	15	9	28
6	Limestone, nitrogen, phosphorus	26	20	18	18	30
9	Limestone, nitrogen, phosphorus, potassium	31	34	21	20	26
8	Limestone, phosphorus, potassium	3	3	5	3	7

(c) TERRACE SOILS

Terrace soils were formed on terraces or old fills in valleys. The terraces owe their formation generally to the deposition of material from an overloaded and flooded stream during the melting of the glaciers. The material varied from fine to coarse. These valleys were sometimes filled almost to the height of the upland. Later the streams cut down thru these fills and developed new bottom lands, or flood plains, at a lower level, leaving part of the old fill as a terrace. The lowest and most recently formed bottom land is called first bottom. The higher land no longer flooded (or very rarely, at most) is generally designated as second bottom. Finer material later deposited on this sand and gravel of the fill now constitutes the soil. The terraces occur along the Mackinaw and Sangamon rivers.

Brown Silt Loam over Gravel (1527)

Brown silt loam over gravel occurs along the Sangamon river in very limited areas. The total area is only 166 acres.

The surface soil, 0 to 6⅔ inches, is a brown to a dark brown silt loam, containing some sand and 5.7 percent of organic matter, or 57 tons per acre. The topography is slightly undulating.

The subsurface soil varies from a brown to a yellowish brown or yellowish drab silt loam, and the lower part of the stratum at a depth of 16 to 18 inches contains fragments of sand and gravel.

The subsoil is a yellowish or drab-colored silt or clayey silt, which becomes quite gravelly at 35 to 48 inches and passes into rather a pure gravel.

This type, as a rule, is well drained, because of the pervious character of the subsoil. The treatment should be the same as for brown silt loam, except that the addition of phosphorus is not likely to be profitable, because of the deep feeding range afforded plant roots.

Brown Silt Loam on Gravel (1526.2)

Brown silt loam on gravel covers an area of 1.77 square miles (1,132 acres), or only .15 percent of the total area of the county. It differs from the brown silt loam over gravel only in the fact that gravel is within 30 inches of the surface. Because of the nearness of the gravel the type is more susceptible to drouth than if this stratum were deeper.

The treatment for this type should be practically the same as for the preceding. There is, however, a greater necessity for increasing the organic matter, because the soil contains less of that constituent.

Yellow-Gray Silt Loam on Gravel (1534.2)

Yellow-gray silt loam on gravel is found along both the Mackinaw and Sangamon rivers. It represents the terrace soil that has been covered by a growth of trees and is consequently low in organic matter. The total area is 621 acres.

The surface soil, 0 to 6⅔ inches, is a yellow or yellowish gray silt loam with an organic-matter content of 3.1 percent, or 31 tons per acre.

The subsurface is a yellow silt loam containing a perceptible amount of sand.

The subsoil is a yellow silt or clayey silt, passing into the gravel at a depth of 12 to 30 inches. Local borings are obtained where the gravel layer may be slightly below 30 inches.

This soil needs nitrogen and organic matter as the most essential things in its improvement.

(d) SWAMP AND BOTTOM-LAND SOILS

Deep Peat (1401)

A few small areas of deep peat, aggregating 83 acres, are mapped in this county. They occur in low, poorly drained places in bottom land or swamps.

The surface soil, 0 to 6⅔ inches, is black, generally well decomposed, and contains about 55 percent of organic matter. The subsurface is very similar to the surface, but the organic-matter content is not so high, being about 50 percent. The subsoil is quite variable; in some places it passes into a drab silty clay and in others it is peaty to a depth of 40 inches. It frequently contains shells mingling with the organic matter.

Drainage is of course the first essential for this type. If it does not produce well when drained, trials should be made with potassium. (See Bulletin 157.)

Deep Brown Silt Loam (*Bottom Land*) (1426)

Deep brown silt loam occurs along the streams, chiefly in the southwestern part of the county. It aggregates 23.88 square miles, or 2 percent of the county.

The surface soil, 0 to 6⅔ inches, is a brown silt loam containing from 5 to 8 percent of organic matter. It varies somewhat in physical composition from a heavy phase to one containing sand in sufficient amounts to be called a sandy loam. This latter, however, does not occur in areas large enough to be mapped.

The subsurface soil is similar to the surface except that the organic-matter content is slightly lower, varying from 4 to 7 percent, and consequently the soil is a little lighter in color. The subsoil is not so dark as the surface and contains local areas of coarse material.

Where proper drainage is secured, this type is very productive. As a rule, where it is subject to frequent overflow nothing else is needed except good farming. Even the systematic rotation of crops is not so important where the land is subject to occasional overflow; but where it lies high or is protected from overflow by dikes, a rotation including legume crops should be practiced, and ultimately provision should be made for the enrichment of such protected land in both phosphorus and organic matter, and, if acid, in limestone.

Mixed Loam (*Bottom Land*) (1454)

Mixed loam occurs chiefly north of the Bloomington moraine. It aggregates 18 square miles, or 1.5 percent of the county. It varies quite widely in its physical composition, including sand, sandy loam, silt loam, and possibly some clay loam. Its character changes more or less with each flood; hence it is impracticable to attempt to separate it into distinct types. The amount of organic matter in the surface soil is about 5.5 percent, which is equivalent to 55 tons per acre.

The subsurface is a dark soil, varying in physical composition from a sandy loam to a clay loam. The organic-matter content is about 4.6 percent.

The subsoil is slightly lighter in color than the subsurface, with a variable composition similar to that of the other strata.

This type is fertile, and no treatment is suggested beyond that mentioned for the preceding type, deep brown silt loam.

APPENDIX

A study of the soil map and the tabular statements concerning crop requirements, the plant-food content of the different soil types, and the actual results secured from definite field trials with different methods or systems of soil improvement, and a careful study of the discussion of general principles and of the descriptions of individual soil types, will furnish the most necessary and useful information for the practical improvement and permanent preservation of the productive power of every kind of soil on every farm in the county.

More complete information concerning the most extensive and important soil types in the great soil areas in all parts of Illinois is contained in Bulletin 123, "The Fertility in Illinois Soils," which contains a colored general soil-survey map of the entire state.

Other publications of general interest are:

Bulletin No. 76, "Alfalfa on Illinois Soils"
Bulletin No. 94, "Nitrogen Bacteria and Legumes"
Bulletin No. 115, "Soil Improvement for the Worn Hill Lands of Illinois"
Bulletin No. 125, "Thirty Years of Crop Rotation on the Common Prairie Lands of Illinois"
Circular No. 82, "Physical Improvement of Soils"
Circular No. 110, "Ground Limestone for Acid Soils"
Circular No. 127, "Shall We Use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils?"
Circular No. 129, "The Use of Commercial Fertilizers"
Circular No. 149, "Results of Scientific Soil Treatment" and "Methods and Results of Ten Years' Soil Investigation in Illinois"
Circular No. 165, "Shall We Use 'Complete' Commercial Fertilizers in the Corn Belt?"
Circular No. 167, "The Illinois System of Permanent Fertility"

Note.—Information as to where to obtain limestone, phosphate, bone meal, and potassium salts, methods of application, etc., will also be found in Circulars 110 and 165.

Soil Survey Methods

The detail soil survey of a county consists essentially of ascertaining, and indicating on a map, the location and extent of the different soil types; and, since the value of the survey depends upon its accuracy, every reasonable means is employed to make it trustworthy. To accomplish this object three things are essential: first, careful, well-trained men to do the work; second, an accurate base map upon which to show the results of the work; and, third, the means necessary to enable the men to place the soil-type boundaries, streams, etc., accurately upon the map.

The men selected for the work must be able to keep their location exactly and to recognize the different soil types, with their principal variations and limits, and they must show these upon the maps correctly. A definite system is employed in checking up this work. As an illustration, one soil expert will survey and map a strip 80 rods or 160 rods wide and any convenient length, while his associate will work independently on another strip adjoining this area, and, if the work is correctly done, the soil type boundaries must match up on the line between the two strips.

An accurate base map for field use is absolutely necessary for soil mapping. The base maps are made on a scale of one inch to the mile. The official data of the original or subsequent land survey are used as a basis in the construction of these maps, while the most trustworthy county map available is used in

locating temporarily the streams, roads, and railroads. Since the best of these published maps have some inaccuracies, the location of every road, stream, and railroad must be verified by the soil surveyors, and corrected if wrongly located. In order to make these verifications and corrections, each survey party is provided with an odometer for measuring distances, and a plane table for determining directions of angling roads, railroads, etc.

Each surveyor is provided with a base map of the proper scale, which is carried with him in the field; and the soil-type boundaries, ditches, streams, and necessary corrections are placed in their proper locations upon the map while the mapper is on the area. Each section, or square mile, is divided into 40-acre plots on the map, and the surveyor must inspect every ten acres and determine the type or types of soil composing it. The different types are indicated on the map by different colors, pencils for this purpose being carried in the field.

A small auger 40 inches long forms for each man an invaluable tool with which he can quickly secure samples of the different strata for inspection. An extension for making the auger 80 inches long is carried by each party, so that any peculiarity of the deeper subsoil layers may be studied. Each man carries a compass to aid in keeping directions. Distances along roads are measured by an odometer attached to the axle of the vehicle, while distances in the field off the roads are determined by pacing, an art in which the men become expert by practice. The soil boundaries can thus be located with as high a degree of accuracy as can be indicated by pencil on the scale of one inch to the mile.

SOIL CHARACTERISTICS

The unit in the soil survey is the soil type, and each type possesses more or less definite characteristics. The line of separation between adjoining types is usually distinct, but sometimes one type grades into another so gradually that it is very difficult to draw the line between them. In such exceptional cases, some slight variation in the location of soil-type boundaries is unavoidable.

Several factors must be taken into account in establishing soil types. These are (1) the geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial, or cumulose; (2) the topography, or lay of the land; (3) the native vegetation, as forest or prairie grasses; (4) the structure, or the depth and character of the surface, subsurface, and subsoil; (5) the physical, or mechanical, composition of the different strata composing the soil, as the percentages of gravel, sand, silt, clay, and organic matter which they contain; (6) the texture, or porosity, granulation, friability, plasticity, etc.; (7) the color of the strata; (8) the natural drainage; (9) the agricultural value, based upon its natural productiveness; (10) the ultimate chemical composition and reaction.

The common soil constituents are indicated in the following outline:

Soil constituents	Organic matter	Comprising undecomposed and partially decayed vegetable or organic material	
	Inorganic matter	Clay	.001 mm.[1] and less
		Silt	.001 mm. to .03 mm.
		Sands	.03 mm. to 1. mm.
		Gravel	1. mm. to 32 mm.
		Stones	32. mm. and over

Further discussion of these constituents is given in Circular 82.

[1] 25 millimeters equal 1 inch.

Groups of Soil Types

The following gives the different general groups of soils:

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or silt.

Peaty loams—15 to 35 percent of organic matter mixed with much sand. Some silt and a little clay may be present.

Mucks—15 to 35 percent of partly decomposed organic matter mixed with much clay and silt.

Clays—Soils with more than 25 percent of clay, usually mixed with much silt.

Clay loams—Soils with from 15 to 25 percent of clay, usually mixed with much silt and some sand.

Silt loams—Soils with more than 50 percent of silt and less than 15 percent of clay, mixed with some sand.

Loams—Soils with from 30 to 50 percent of sand mixed with much silt and a little clay.

Sandy loams—Soils with from 50 to 75 percent of sand.

Fine sandy loams—Soils with from 50 to 75 percent of fine sand mixed with much silt and little clay.

Sands—Soils with more than 75 percent of sand.

Gravelly loams—Soils with 25 to 50 percent of gravel with much sand and some silt.

Gravels—Soils with more than 50 percent of gravel and much sand.

Stony loams—Soils containing a considerable number of stones over one inch in diameter.

Rock outcrop—Usually ledges of rock having no direct agricultural value.

More or less organic matter is found in all the above groups.

Supply and Liberation of Plant Food

The productive capacity of land in humid sections depends almost wholly upon the power of the soil to feed the crop; and this, in turn, depends both upon the stock of plant food contained in the soil and upon the rate at which it is liberated, or rendered soluble and available for use in plant growth. Protection from weeds, insects, and fungous diseases, tho exceedingly important, is not a positive but a negative factor in crop production.

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but the rate of liberation is governed by many factors, some of which may be controlled by the farmer, while others are largely beyond his control. Chief among the important controllable factors which influence the liberation of plant food are limestone and decaying organic matter, which may be added to the soil by direct application of ground limestone and farm manure. Organic matter may be supplied also by green-manure crops and crop residues, such as clover, cowpeas, straw, and corn stalks. The rate of decay of organic matter depends largely upon its age and origin, and it may be hastened by tillage. The chemical analysis shows correctly the

total organic carbon, which represents, as a rule, but little more than half the organic matter; so that 20,000 pounds of organic carbon in the plowed soil of an acre correspond to nearly 20 tons of organic matter. But this organic matter consists largely of the old organic residues that have accumulated during the past centuries because they were resistant to decay, and 2 tons of clover or cowpeas plowed under may have greater power to liberate plant food than the 20 tons of old, inactive organic matter. The recent history of the individual farm or field must be depended upon for information concerning recent additions of active organic matter, whether in applications of farm manure, in legume crops, or in grass-root sods of old pastures.

Probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that with the normal rainfall of Illinois the productive power of the land depends primarily upon the stock of plant food contained in the soil and upon the rate at which it is liberated, just as the success of the merchant depends primarily upon his stock of goods and the rapidity of sales. In both cases the stock of any commodity must be increased or renewed whenever the supply of such commodity becomes so depleted as to limit the success of the business, whether on the farm or in the store.

As the organic matter decays, certain decomposition products are formed, including much carbonic acid, some nitric acid, and various organic acids, and these have power to act upon the soil and dissolve the essential mineral plant foods, thus furnishing soluble phosphates, nitrates, and other salts of potassium, magnesium, calcium, etc., for the use of the growing crop.

As already explained, fresh organic matter decomposes much more rapidly than old humus, which represents the organic residues most resistant to decay and which consequently has accumulated in the soil during the past centuries. The decay of this old humus can be hastened both by tillage, which maintains a porous condition and thus permits the oxygen of the air to enter the soil more freely and to effect the more rapid oxidation of the organic matter, and also by incorporating with the old, resistant residues some fresh organic matter, such as farm manure, clover roots, etc., which decay rapidly and thus furnish or liberate organic matter and inorganic food for bacteria, the bacteria, under such favorable conditions, appearing to have power to attack and decompose the old humus. It is probably for this reason that peat, a very inactive and inefficient fertilizer when used by itself, becomes much more effective when composted with fresh farm manure; so that two tons of the compost[1] may be worth as much as two tons of manure, but if applied separately, the peat has little value. Bacterial action is also promoted by the presence of limestone.

The condition of the organic matter of the soil is indicated more or less definitely by the ratio of carbon to nitrogen. As an average, the fresh organic

[1]In his book, "Fertilizers," published in 1839, Cuthbert W. Johnson reported such compost to have been much used in England and to be valued as highly, "weight for weight, as farm-yard dung."

matter incorporated with soils contains about twenty times as much carbon as nitrogen, but the carbohydrates ferment and decompose much more rapidly than the nitrogenous matter; and the old resistant organic residues, such as are found in normal subsoils, commonly contain only five or six times as much carbon as nitrogen. Soils of normal physical composition, such as loam, clay loam, silt loam, and fine sandy loam, when in good productive condition, contain about twelve to fourteen times as much carbon as nitrogen in the surface soil; while in old, worn soils that are greatly in need of fresh, active, organic manures, the ratio is narrower, sometimes falling below ten of carbon to one of nitrogen. Soils of cut-over or burnt-over timber lands sometimes contain so much partially decayed wood or charcoal as to destroy the value of the nitrogen-carbon ratio for the purpose indicated. (Except in newly made alluvial soils, the ratio is usually narrower in the subsurface and subsoil than in the surface stratum.)

It should be kept in mind that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all agricultural plants, only one (hydrogen) from water, and seven from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes), in case the amount liberated from the soil is insufficient; but even these plants (which include only the clovers, peas, beans, and vetches, among our common agricultural plants) secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron, and sulfur), and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Plants are made of plant-food elements in just the same sense that a building is made of wood and iron, brick, stone, and mortar. Without materials, nothing material can be made. The normal temperature, sunshine, rainfall, and length of season in central Illinois are sufficient to produce 50 bushels of wheat per acre, 100 bushels of corn, 100 bushels of oats, and 4 tons of clover hay; and, where the land is properly drained and properly tilled, such crops would frequently be secured *if the plant foods were present in sufficient amounts and liberated at a sufficiently rapid rate to meet the absolute needs of the crops.*

Crop Requirements

The accompanying table shows the requirements of wheat, corn, oats, and clover for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally in sufficient abundance compared with the amounts needed by plants, so that they are never known to limit the yield of general farm crops grown under normal conditions.)

To be sure, these are large yields, but shall we try to make possible the production of yields only half or a quarter as large as these, or shall we set as our ideal this higher mark, and then approach it as nearly as possible with profit? Among the four crops, corn is the largest, with a total yield of more than six tons per acre; and yet the 100-bushel crop of corn is often produced on rich pieces of land in good seasons. In very practical and profitable systems

TABLE A.—PLANT FOOD IN WHEAT, CORN, OATS, AND CLOVER

Produce		Nitrogen	Phosphorus	Potassium	Magnesium	Calcium
Kind	Amount					
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Wheat, grain.......	50 bu.	71	12	13	4	1
Wheat straw........	2½ tons	25	4	45	4	10
Corn, grain..........	100 bu.	100	17	19	7	1
Corn stover.........	3 tons	48	6	52	10	21
Corn cobs..........	½ ton	2		2		
Oats, grain..........	100 bu.	66	11	16	4	2
Oat straw..........	2½ tons	31	5	52	7	15
Clover seed.........	4 bu.	7	2	3	1	1
Clover hay.........	4 tons	160	20	120	31	117
Total in grain and seed..................		244[1]	42	51	16	4
Total in four crops......................		510[1]	77	322	68	168

[1]These amounts include the nitrogen contained in the clover seed or hay, which, however, may be secured from the air.

of farming, the Illinois Experiment Station has produced, as an average of the six years 1905 to 1910, a yield of 87 bushels of corn per acre in grain farming (with limestone and phosphorus applied, and with crop residues and legume crops turned under), and 90 bushels per acre in live-stock farming (with limestone, phosphorus, and manure).

The importance of maintaining a rich surface soil cannot be too strongly emphasized. This is well illustrated by data from the Rothamsted Experiment Station, the oldest in the world. On Broadbalk field, where wheat has been grown since 1844, the average yields for the ten years 1892 to 1901 were 12.3 bushels per acre on Plot 3 (unfertilized) and 31.8 bushels on Plot 7 (well fertilized), but the amounts of both nitrogen and phosphorus in the subsoil (9 to 27 inches) were distinctly greater in Plot 3 than in Plot 7, thus showing that the higher yields from Plot 7 were due to the fact that the plowed soil had been enriched. In 1893 Plot 7 contained per acre in the surface soil (0 to 9 inches) about 600 pounds more nitrogen and 900 pounds more phosphorus than Plot 3. Even a rich subsoil has little value if it lies beneath a worn-out surface.

METHODS OF LIBERATING PLANT FOOD

Limestone and decaying organic matter are the principal materials which the farmer can utilize most profitably to bring about the liberation of plant food. The limestone corrects the acidity of the soil and thus encourages the development not only of the nitrogen-gathering bacteria which live in the nodules on the roots of clover, cowpeas, and other legumes, but also the nitrifying bacteria, which have power to transform the insoluble and unavailable organic nitrogen into soluble and available nitrate nitrogen. At the same time, the products of this decomposition have power to dissolve the minerals contained in the soil, such as potassium and magnesium, and also to dissolve the insoluble phosphate and limestone which may be applied in low-priced forms.

Tillage, or cultivation, also hastens the liberation of plant food by permitting the air to enter the soil and burn out the organic matter; but it should never be forgotten that tillage is wholly destructive, that it adds nothing what-

ever to the soil, but always leaves it poorer. Tillage should be practiced so far as is necessary to prepare a suitable seed bed for root development and also for the purpose of killing weeds, but more than this is unnecessary and unprofitable in seasons of normal rainfall; and it is much better actually to enrich the soil by proper applications or additions, including limestone and organic matter (both of which have power to improve the physical condition as well as to liberate plant food) than merely to hasten soil depletion by means of excessive cultivation.

Permanent Soil Improvement

The best and most profitable methods for the permanent improvement of the common soils of Illinois are as follows:

(1) If the soil is acid, apply at least two tons per acre of ground limestone, preferably at times magnesian limestone ($CaCO_3MgCO_3$), which contains both calcium and magnesium and has slightly greater power to correct soil acidity, ton for ton, than the ordinary calcium limestone ($CaCO_3$); and continue to apply about two tons per acre of ground limestone every four or five years. On strongly acid soils, or on land being prepared for alfalfa, five tons per acre of ground limestone may well be used for the first application.

(2) Adopt a good rotation of crops, including a liberal use of legumes, and increase the organic matter of the soil either by plowing under the legume crops and other crop residues (straw and corn stalks), or by using for feed and bedding practically all the crops raised and returning the manure to the land with the least possible loss. No one can say in advance what will prove to be the best rotation of crops, because of variation in farms and farmers, and in prices for produce, but the following are suggested to serve as models or outlines:

First year, corn.
Second year, corn.
Third year, wheat or oats (with clover or clover and grass).
Fourth year, clover or clover and grass.
Fifth year, wheat and clover or grass and clover.
Sixth year, clover or clover and grass.

Of course there should be as many fields as there are years in the rotation. In grain farming, with small grain grown the third and fifth years, most of the coarse products should be returned to the soil, and the clover may be clipped and left on the land (only the clover seed being sold the fourth and sixth years); or, in live-stock farming, the field may be used three years for timothy and clover pasture and meadow if desired. The system may be reduced to a five-year rotation by cutting out either the second or the sixth year, and to a four-year system by omitting the fifth and sixth years.

With two years of corn, followed by oats with clover-seeding the third year, and by clover the fourth year, all produce can be used for feed and bedding if other land is available for permanent pasture. Alfalfa may be grown on a fifth field for four or eight years, which is to be alternated with one of the four; or the alfalfa may be moved every five years, and thus rotated over all five fields every twenty-five years.

Other four-year rotations more suitable for grain farming are:

Wheat (and clover), corn, oats, and clover; or corn (and clover), cowpeas, wheat, and clover. (Alfalfa may be grown on a fifth field and rotated every five years, the hay being sold.)

Good three-year rotations are:

Corn, oats, and clover; corn, wheat, and clover; or wheat (and clover), corn (and clover), and cowpeas, in which two cover crops and one regular crop of legumes are grown in three years.

A five-year rotation of (1) corn (and clover), (2) cowpeas, (3) wheat, (4) clover, and (5) wheat (and clover) allows legumes to be seeded four times. Alfalfa may be grown on a sixth field for five or six years in the combination rotation, alternating between two fields every five years, or rotating over all the fields if moved every six years.

To avoid clover sickness it may sometimes be necessary to substitute sweet clover or alsike for red clover in about every third rotation, and at the same time to discontinue its use in the cover-crop mixture. If the corn crop is not too rank, cowpeas or soybeans may also be used as a cover crop (seeded at the last cultivation) in the southern part of the state, and, if necessary to avoid disease, these may well alternate in successive rotations.

For easy figuring it may well be kept in mind that the following amounts of nitrogen are required for the produce named:

1 bushel of oats (grain and straw) requires 1 pound of nitrogen.
1 bushel of corn (grain and stalks) requires 1½ pounds of nitrogen.
1 bushel of wheat (grain and straw) requires 2 pounds of nitrogen.
1 ton of timothy requires 24 pounds of nitrogen.
1 ton of clover contains 40 pounds of nitrogen.
1 ton of cowpeas contains 43 pounds of nitrogen.
1 ton of average manure contains 10 pounds of nitrogen.

The roots of clover contain about half as much nitrogen as the tops, and the roots of cowpeas contain about one-tenth as much as the tops.

Soils of moderate productive power will furnish as much nitrogen to clover (and two or three times as much to cowpeas) as will be left in the roots and stubble. In grain crops, such as wheat, corn, and oats, about two-thirds of the nitrogen is contained in the grain and one-third in the straw or stalks. (See also discussion of ''The Potassium Problem,'' on pages following.)

(3) On all lands deficient in phosphorus (except on those susceptible to serious erosion by surface washing or gullying) apply that element in considerably larger amounts than are required to meet the actual needs of the crops desired to be produced. The abundant information thus far secured shows positively that fine-ground natural rock phosphate can be used successfully and very profitably, and clearly indicates that this material will be the most economical form of phosphorus to use in all ordinary systems of permanent, profitable soil improvement. The first application may well be one ton per acre, and subsequently about one-half ton per acre every four or five years should be applied, at least until the phosphorus content of the plowed soil reaches 2,000 pounds per acre, which may require a total application of from three to five or six tons per acre of raw phosphate containing 12½ percent of the element phosphorus.

Steamed bone meal and even acid phosphate may be used in emergencies, but it should always be kept in mind that phosphorus delivered in Illinois costs about 3 cents a pound in raw phosphate (direct from the mine in carload lots), but 10 cents a pound in steamed bone meal, and about 12 cents a pound in acid phosphate, both of which cost too much per ton to permit their common purchase by farmers in carload lots, which is not the case with limestone or raw phosphate.

Phosphorus once applied to the soil remains in it until removed in crops, unless carried away mechanically by soil erosion. (The loss by leaching is only about 1½ pounds per acre per annum, so that more than 150 years would be required to leach away the phosphorus applied in one ton of raw phosphate.)

The phosphate and limestone may be applied at any time during the rotation, but a good method is to apply the limestone after plowing and work it into the surface soil in preparing the seed bed for wheat, oats, rye, or barley, where clover is to be seeded; while phosphate is best plowed under with farm manure, clover, or other green manures, which serve to liberate the phosphorus.

(4) Until the supply of decaying organic matter has been made adequate, on the poorer types of upland timber and gray prairie soils some temporary benefit may be derived from the use of a soluble salt or a mixture of salts, such as kainit, which contains both potassium and magnesium in soluble form and also some common salt (sodium chlorid). About 600 pounds per acre of kainit applied and turned under with the raw phosphate will help to dissolve the phosphorus as well as to furnish available potassium and magnesium, and for a few years such use of kainit may be profitable on lands deficient in organic matter, but the evidence thus far secured indicates that its use is not absolutely necessary and that it will not be profitable after adequate provision is made for supplying decaying organic matter, since this will necessitate returning to the soil the potassium contained in the crop residues from grain farming or the manure produced in live-stock farming, and will also provide for the liberating of potassium from the soil. (Where hay or straw is sold, manure should be bought.)

On soils which are subject to surface washing, including especially the yellow silt loam of the upland timber area, and to some extent the yellow-gray silt loam and other more rolling areas, the supply of minerals in the subsurface and subsoil (which gradually renew the surface soil) tends to provide for a low-grade system of permanent agriculture if some use is made of legume plants, as in long rotations with much pasture, because both the minerals and nitrogen are thus provided in some amount almost permanently; but where such lands are farmed under such a system, not more than two or three grain crops should be grown during a period of ten or twelve years, the land being kept in pasture most of the time; and where the soil is acid a liberal use of limestone, as top-dressings if necessary, and occasional reseeding with clovers will benefit both the pasture and indirectly the grain crops.

Advantage of Crop Rotation and Permanent Systems

It should be noted that clover is not likely to be well infected with the clover bacteria during the first rotation on a given farm or field where it has not been grown before within recent years; but even a partial stand of clover the first time will probably provide a thousand times as many bacteria for the next clover crop as one could afford to apply in artificial inoculation, for a single root-tubercle may contain a million bacteria developed from one during the season's growth.

This is only one of several advantages of the second course of the rotation over the first course. Thus the mere practice of crop rotation is an advantage, especially in helping to rid the land of insects and foul grass and weeds. The clover crop is an advantage to subsequent crops because of its deep-rooting char-

acteristic. The larger applications of organic manures (made possible by the larger crops) are a great advantage; and in systems of permanent soil improvement, such as are here advised and illustrated, more limestone and more phosphorus are provided than are needed for the meager or moderate crops produced during the first rotation, and consequently the crops in the second rotation have the advantage of such accumulated residues (well incorporated with the plowed soil) in addition to the regular applications made during the second rotation.

This means that these systems tend positively toward the making of richer lands. The ultimate analyses recorded in the tables give the absolute invoice of these Illinois soils. They show that most of them are positively deficient only in limestone, phosphorus, and nitrogenous organic matter; and the accumulated information from careful and long-continued investigations in different parts of the United States clearly establishes the fact that in general farming these essentials can be supplied with greatest economy and profit by the use of ground natural limestone, very finely ground natural rock phosphate, and legume crops to be plowed under directly or in farm manure. On normal soils no other applications are absolutely necessary, but, as already explained, the addition of some soluble salt in the beginning of a system of improvement on some of these soils produces temporary benefit, and if some inexpensive salt, such as kainit, is used, it may produce sufficient increase to more than pay the added cost.

The Potassium Problem

As reported in Illinois Bulletin 123, where wheat has been grown every year for more than half a century at Rothamsted, England, exactly the same increase was produced (5.6 bushels per acre), as an average of the first 24 years, whether potassium, magnesium, or sodium was applied, the rate of application per annum being 200 pounds of potassium sulfate and molecular equivalents of magnesium sulfate and sodium sulfate. As an average of 60 years (1852 to 1911), the yield of wheat was 12.7 bushels on untreated land and 23.3 bushels where 86 pounds of nitrogen and 29 pounds of phosphorus per acre per annum were applied. As further additions, 85 pounds of potassium raised the yield to 31.3 bushels; 52 pounds of magnesium raised it to 29.2 bushels; and 50 pounds of sodium raised it to 29.5 bushels. Where potassium was applied, the wheat crop removed annually an average of 40 pounds of that element in the grain and straw, or three times as much as would be removed in the grain only for such crops as are suggested in Table A. The Rothamsted soil contained an abundance of limestone, but no organic matter was provided except the little in the stubble and roots of the wheat plants.

On another field at Rothamsted the average yield of barley for 60 years (1852 to 1911) was 14.2 bushels on untreated land, 38.1 bushels where 43 pounds of nitrogen and 29 pounds of phosphorus were applied per acre per annum; while the further addition of 85 pounds of potassium, 19 pounds of magnesium, and 14 pounds of sodium (all in sulfates) raised the average yield to 41.5 bushels. Where only 70 pounds of sodium were applied in addition to the nitrogen and phosphorus, the average was 43.0 bushels. Thus, as an average of 60 years, the use of sodium produced 1.8 bushels less wheat and 1.5 bushels

more barley than the use of potassium, with both grain and straw removed and no organic manures returned.

In recent years the effect of potassium is becoming much more marked than that of sodium or magnesium, on the wheat crop; but this must be expected to occur in time where no potassium is returned in straw or manure, and no provision made for liberating potassium from the supply still remaining in the soil. If the wheat straw, which contains more than three-fourths of the potassium removed in the wheat crop (see Table A), were returned to the soil, the necessity of purchasing potassium in a good system of farming on such land would be at least very remote, for the supply would be adequately maintained by the actual amount returned in the straw, together with the additional amount which would be liberated from the soil by the action of decomposition products.

While about half the potassium, nitrogen, and organic matter, and about one-fourth the phosphorus contained in manure is lost by three or four months' exposure in the ordinary pile in the barn yard, there is practically no loss if plenty of absorbent bedding is used on cement floors, and if the manure is hauled to the field and spread within a day or two after it is produced. Again, while in average live-stock farming the animals destroy two-thirds of the organic matter and retain one-fourth of the nitrogen and phosphorus from the food they consume, they retain less than one-tenth of the potassium; so that the actual loss of potassium in the products sold from the farm, either in grain farming or in live-stock farming, is wholly negligible on land containing 25,000 pounds or more of potassium in the surface 6⅔ inches.

The removal of one inch of soil per century by surface washing (which is likely to occur wherever there is satisfactory surface drainage and frequent cultivation) will permanently maintain the potassium in grain farming by renewal from the subsoil, provided one-third of the potassium is removed by cropping before the soil is carried away.

From all these facts it will be seen that the potassium problem is not one of addition but of liberation; and the Rothamsted records show that for many years other soluble salts have practically the same power as potassium to increase crop yields in the absence of sufficient decaying organic matter. Whether this action relates to supplying or liberating potassium for its own sake, or to the power of the soluble salt to increase the availability of phosphorus or other elements, is not known, but where much potassium is removed, as in the entire crops at Rothamsted, with no return of organic residues, probably the soluble salt functions in both ways.

As an average of 112 separate tests conducted in 1907, 1908, 1909, and 1910 on the Fairfield experiment field, an application of 200 pounds of potassium sulfate, containing 85 pounds of potassium and costing $5.10, increased the yield of corn by 9.3 bushels per acre; while 600 pounds of kainit, containing only 60 pounds of potassium and costing $4, gave an increase of 10.7 bushels. Thus, at 40 cents a bushel for corn, the kainit paid for itself; but these results, like those at Rothamsted, were secured where no adequate provision had been made for decaying organic matter.

Additional experiments at Fairfield included an equally complete test with potassium sulfate and kainit on land to which 8 tons per acre of farm manure

were applied. As an average of 112 tests with each material, the 200 pounds of potassium sulfate increased the yield of corn by 1.7 bushels, while the 600 pounds of kainit also gave an increase of 1.7 bushels. Thus, where organic manure was supplied, very little effect was produced by the addition of either potassium sulfate or kainit; in part perhaps because the potassium removed in the crops is mostly returned in the manure if properly cared for, and perhaps in larger part because the decaying organic matter helps to liberate and hold in solution other plant-food elements, especially phosphorus.

In laboratory experiments at the Illinois Experiment Station, it has been shown by chemical analysis that potassium salts and most other soluble salts increase the solubility of the phosphorus in soil and in rock phosphate; also that the addition of glucose with rock phosphate in pot-culture experiments increases the availability of the phosphorus, as measured by plant growth, altho the glucose consists only of carbon, hydrogen, and oxygen, and thus contains no plant food of value.

If we remember that, as an average, live stock destroy two-thirds of the organic matter of the food they consume, it it easy to determine from Table A that more organic matter will be supplied in a proper grain system than in a strictly live-stock system; and the evidence thus far secured from older experiments at the University and at other places in the state indicates that if the corn stalks, straw, clover, etc., are incorporated with the soil as soon as practicable after they are produced (which can usually be done in the late fall or early spring), there is little or no difficulty in securing sufficient decomposition in our humid climate to avoid serious interference with the capillary movement of the soil moisture, a common danger from plowing under too much coarse manure of any kind in the late spring of a dry year.

If, however, the entire produce of the land is sold from the farm, as in hay farming or when both grain and straw are sold, of course the draft on potassium will then be so great that in time it must be renewed by some sort of application. As a rule, farmers following this practice ought to secure manure from town, since they furnish the bulk of the material out of which manure is produced.

Calcium and Magnesium

When measured by the actual crop requirements for plant food, magnesium and calcium are more limited in some Illinois soils than potassium. But with these elements we must also consider the loss by leaching. As an average of 90 analyses[1] of Illinois well-waters drawn chiefly from glacial sands, gravels, or till, 3 million pounds of water (about the average annual drainage per acre for Illinois) contained 11 pounds of potassium, 130 of magnesium, and 330 of calcium. These figures are very significant, and it may be stated that if the plowed soil is well supplied with the carbonates of magnesium and calcium, then a very considerable proportion of these amounts will be leached from that stratum. Thus the loss of calcium from the plowed soil of an acre at Rothamsted, England, where the soil contains plenty of limestone, has averaged more than 300 pounds a year as determined by analyzing the soil in 1865 and again in 1905. Practically the same amount of calcium was found, by analyses, in the Rothamsted drainage waters.

[1]Reported by Doctor Bartow and associates, of the Illinois State Water Survey.

Common limestone, which is calcium carbonate ($CaCO_3$), contains, when pure, 40 percent of calcium, so that 800 pounds of limestone are equivalent to 320 pounds of calcium. Where 10 tons per acre of ground limestone were applied at Edgewood, Illinois, the average annual loss during the next ten years amounted to 790 pounds per acre. The definite data from careful investigations seem to be ample to justify the conclusion that where limestone is needed at least 2 tons per acre should be applied every 4 or 5 years.

It is of interest to note that thirty crops of clover of four tons each would require 3,510 pounds of calcium, while the most common prairie land of southern Illinois contains only 3,420 pounds of total calcium in the plowed soil of an acre. (See Soil Report No. 1.) Thus limestone has a positive value on some soils for the plant food which it supplies, in addition to its value in correcting soil acidity and in improving the physical condition of the soil. Ordinary limestone (abundant in the southern and western parts of the state) contains nearly 800 pounds of calcium per ton; while a good grade of dolomitic limestone (the more common limestone of northern Illinois) contains about 400 pounds of calcium and 300 pounds of magnesium per ton. Both of these elements are furnished in readily available form in ground dolomitic limestone.

Physical Improvement of Soils

In the management of most soil types, one very important thing, aside from proper fertilization, tillage, and drainage, is to keep the soil in good physical condition, or good tilth. The constituent most important for this purpose is organic matter. Not only does it impart good tilth to the soil, but it prevents much loss by washing on rolling land, warms the soil by absorption of heat, retains moisture during drouth and prevents the soil from running together badly; and, as it decays, it furnishes nitrogen for the crop and aids in the liberation of mineral plant food. This constituent must be supplied to the soil in every practical way, so that the amount may be maintained or even increased. It is being broken down during a large part of the year, and the nitrates produced are used for plant growth. This decomposition is necessary, but it is also quite necessary that the supply be maintained.

The physical effect of organic matter in the soil is to produce a granulation, or mellowness, very favorable for tillage and the development of plant roots. If continuous cropping takes place, accompanied with the removal or the destruction of the corn stalks and straw, the amount of organic matter is gradually diminished and a condition of poor tilth will ultimately follow. In many cases this already limits the crop yields. The remedy is to increase the organic-matter content by plowing under manure or crop residues, such as corn stalks, straw, and clover. Selling these products from the farm, burning them, or feeding them and not returning the manure, or allowing a very large part of the manure to be lost before it is returned to the land, all represent bad practice.

One of the chief sources of loss of organic matter in the corn belt is the practice of burning the corn stalks. Could the farmers be made to realize how great a loss this entails, they would certainly discontinue the practice. Probably no form of organic matter acts more beneficially in producing good tilth than corn stalks. It is true that they decay rather slowly, but it is also true that their

durability in the soil after partial decomposition is exactly what is needed in the maintenance of an adequate supply of humus.

The nitrogen in a ton of corn stalks is 1½ times that in a ton of manure, and a ton of dry corn stalks incorporated with the soil will ultimately furnish as much humus as 4 tons of average farm manure; but when burned, both the humus-making material and the nitrogen which these stalks contain are destroyed and lost to the soil.

The objection is often raised that when stalks are plowed under they interfere very seriously in the cultivation of corn, and thus indirectly destroy a great deal of corn. If corn stalks are well cut up and then turned under to a depth of 5½ to 6 inches when the ground is plowed in the spring, very little trouble will result.

Where corn follows corn, the stalks, if not needed for feeding purposes, should be thoroly cut up with a sharp disk or stalk cutter and turned under. Likewise, the straw should be returned to the land in some practical way, either directly or as manure. Clover should be one of the crops grown in the rotation, and it should be plowed under directly or as manure instead of being sold as hay, except when manure can be brought back.

It must be remembered, however, that in the feeding of hay, or straw, or corn stalks, a great destruction of organic matter takes place, so that even if the fresh manure were returned to the soil, there would still be a loss of 50 to 70 percent owing to the destruction of organic matter by the animal. If manure is allowed to lie in the farmyard for a few weeks or months, there is an additional loss which amounts to from one-third to two-thirds of the manure recovered from the animal. This is well shown by the results of an experiment conducted by the Maryland Experiment Station, where 80 tons of manure were allowed to lie for a year in the farmyard and at the end of that time but 27 tons remained, entailing a loss of about 66 percent of the manure. Most of this loss occurs within the first three or four months, when fermentation, or "heating," is most active. Two tons of manure were exposed from April 29 to August 29, by the Canadian Experiment Station at Ottawa. During these four months the organic matter was reduced from 1,938 pounds to 655 pounds. To obtain the greatest value from the manure, it should be applied to the soil as soon as possible after it is produced.

It is a common practice in the corn belt to pasture the corn stalks during the winter and often rather late in the spring after the frost is out of the ground. This tramping of stock sometimes puts the soil in bad condition for working. It becomes partially puddled and will be cloddy as a result. If tramped too late in the spring, the natural agencies of freezing and thawing, and wetting and drying, with the aid of ordinary tillage, fail to produce good tilth before the crop is to be planted. Whether the crop is corn or oats, it necessarily suffers, and if the season is dry, much damage may result. If the field is put in corn, a poor stand is likely to follow, and if put in oats, a compact soil is formed which is unfavorable for their growth. Sometimes the soil is worked when too wet. This also produces a partial puddling which is unfavorable to physical, chemical, and biological processes. The bad effect will be greater if cropping has reduced the organic matter below the amount necessary to maintain good tilth.